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FINAL

Bioventing Pilot Test and Expanded Treatability Study Work Plan

Site ST10
Hickam Petroleum, Oils, and Lubricants Pipeline

Sites ST12-A and ST12-B
Waikakalaua Fuel Storage Annex

AIR CENTER FOR ENVIRONMENTAL EXCELLENCE

Hickam Air Force Base, Hawaii

Prepared For

Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas

and

15th CES/CEVR
Hickam Air Force Base, Hawaii

September 1995

PARSONS
ENGINEERING SCIENCE, INC.

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FINAL
BIOVENTING PILOT TEST AND EXPANDED TREATABILITY STUDY WORK PLAN

SITE ST10
HICKAM PETROLEUM, OILS, AND LUBRICANTS PIPELINE

SITES ST12-A AND ST12-B
WAIKAKALAUA FUEL STORAGE ANNEX

HICKAM AIR FORCE BASE, HAWAII

Prepared for:

Air Force Center for Environmental Excellence
Brooks Air Force Base, Texas

and

15 CES/CEVR
Hickam Air Force Base, Hawaii

September 1995

Prepared by:

Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
Base	Hickam Air Force Base
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, xylenes
cfm	cubic feet per minute
°C	degrees centigrade
EPA	US Environmental Protection Agency
ERT	Technology Transfer Division
ES	Engineering-Science, Inc.
FSA	Fuel Storage Annex
ft/ft	feet per foot
HLA	Harding Lawson Associates
IDW	investigation-derived waste
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MP	monitoring point
MW	monitoring well
NEC	National Electric Code
O&M	operation and maintenance
OVA	organic vapor analyzer
Parsons ES	Parsons Engineering Science, Inc.
PID	photoionization detector
POL	Petroleum, Oil, and Lubricant
ppmv	parts per million, volume per volume
PVC	polyvinyl chloride
scfm	standard cubic feet per minute
TPH	total petroleum hydrocarbons
TRPH	total recoverable petroleum hydrocarbons

ACRONYMS AND ABBREVIATIONS (Continued)

TVH	total volatile hydrocarbons
UST	underground storage tank
VOC	volatile organic compounds
VW	vent well

FINAL
BIOVENTING PILOT TEST AND EXPANDED TREATABILITY STUDY WORK PLAN

SITE ST10
HICKAM PETROLEUM, OILS, AND LUBRICANTS PIPELINE

SITES ST12-A AND ST12-B
WAIKAKALAUA FUEL STORAGE ANNEX

HICKAM AIR FORCE BASE, HAWAII

1.0 INTRODUCTION

This work plan presents the proposed scope of work for bioventing pilot tests at two sites (ST10 and ST12-B) and the expansion of an existing pilot-scale bioventing system at one site (ST12-A) administered by Hickam Air Force Base (AFB), Hawaii (the Base). The proposed scope of work will be performed by Parsons Engineering Science, Inc. (Parsons ES) [formerly Engineering-Science, Inc. (ES)] for Hickam AFB and the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division (ERT) under contract F41624-92-D-8036, Order 0017.

The pilot tests will be performed to determine the feasibility of bioventing for the remediation of petroleum-contaminated soils at Sites ST10 and ST12-B. Based on previous successful bioventing pilot test results at Site ST12-A, an expanded system will be installed to treat a larger volume of contaminated soils at the site. Site locations are illustrated in Figure 1.1. Sites ST12-A and ST12-B are specific areas located at the Waikakalaua Fuel Storage Annex (FSA), which in its entirety is designated as Site ST12. Site ST10 is located at Valve Pit 17 on the Hickam Petroleum, Oils, and Lubricants (POL) pipeline, which runs from Pearl Harbor to the Waikakalaua FSA. The Kipapa FSA branch of the POL pipeline connects with the Pearl Harbor/Waikakalaua line at Valve Pit 17. The Hickam POL system, including Sites ST10 and ST12, is now out of commission, and site restoration activities are currently underway.

1.1 Bioventing Pilot Tests at Sites ST10 and ST12-B

The primary objectives of the proposed bioventing pilot tests at Sites ST10 and ST12-B are to:

- Provide additional information regarding the extent of contamination at these sites by sampling in areas potentially impacted by fuel hydrocarbons;

- Assess the potential for supplying oxygen throughout contaminated soil intervals;

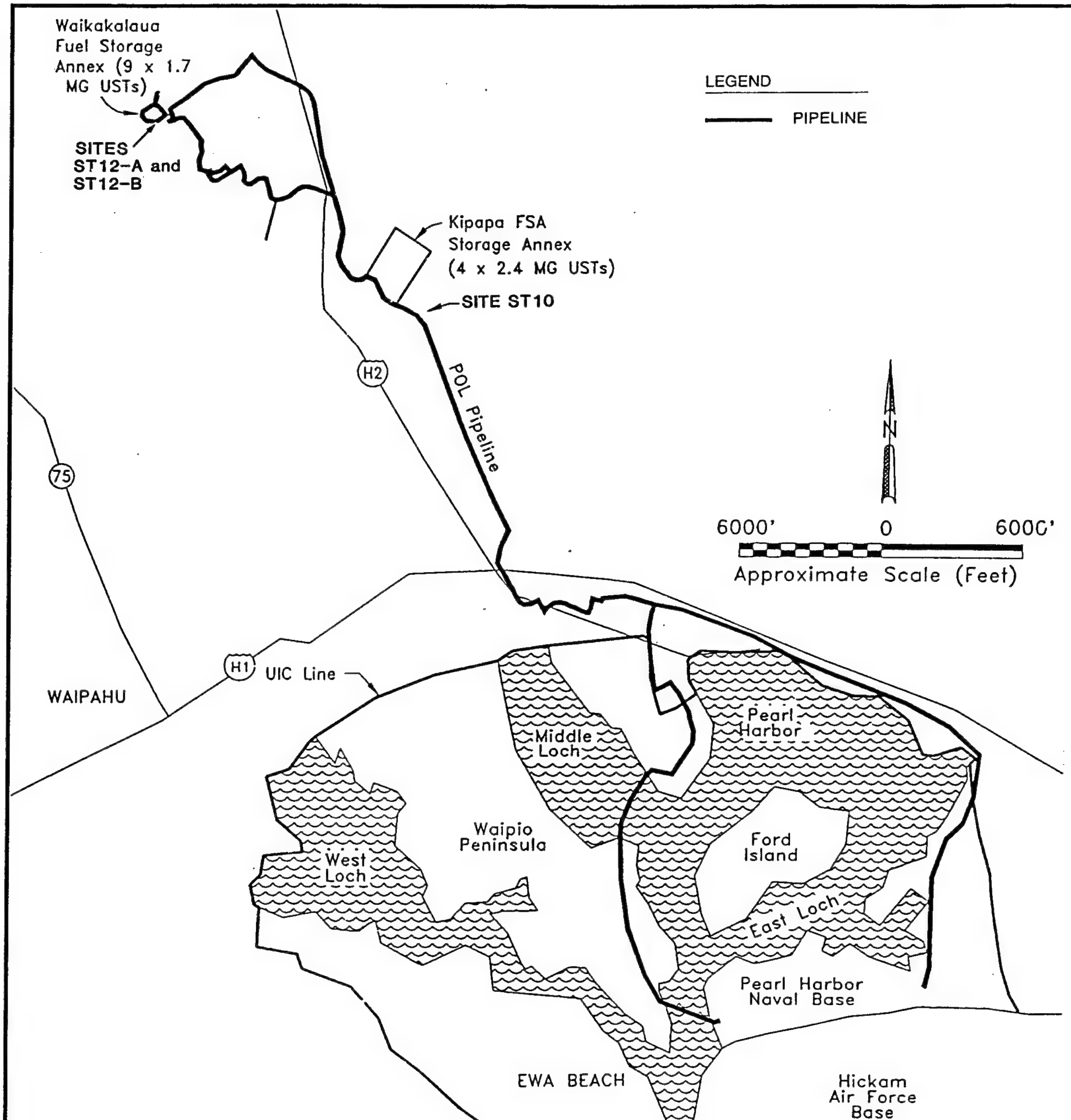

FIGURE 1.1

SITE LOCATIONS
HICKAM POL SYSTEM

Hickam AFB, Hawaii

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- Determine the rate at which indigenous microorganisms will degrade fuel when supplied with oxygen-rich soil gas;
- Evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards; and
- Determine design parameters, such as well spacing and flow rates, for full-scale bioventing system design.

The pilot tests will be conducted in two phases. For each of the two sites, the initial phase will consist of construction of one or two vent wells (VWs) and three to four vapor monitoring points (MPs), initial soil and soil gas characterization, *in situ* respiration tests, and an air permeability test. Existing groundwater monitoring wells may be used as additional MPs or VWs if portions of their screens are in unsaturated soils. A pilot-scale blower system will be installed at each site to inject air into the subsurface. This initial phase, along with system expansion at Site ST12-A, is expected to take approximately 4 weeks. During the second phase, each pilot-scale bioventing system will be operated and monitored for a 1-year period. At the end of this period, *in situ* respiration testing and soil gas sampling will be performed to determine the degree of cleanup achieved over 1 year of pilot-scale system operation.

1.2 Expanded Treatability Study at Site ST12-A

The primary objectives of the expanded bioventing treatability study at Site ST12-A are to:

- Provide additional information regarding the extent of contamination, which has not yet been entirely defined;
- Expand the system to more fully influence the contaminated area;
- Continue *in situ* remediation of fuel-contaminated soils by further stimulation with oxygen-rich soil gas;
- Sustain *in situ* biodegradation until fuel-contaminated soils within shallow portions of the unsaturated zone (i.e., the saprolite) are remediated to approved regulatory standards; and
- Provide the most cost-effective remediation alternative for this site.

The expanded bioventing treatability study at Site ST12-A will be conducted in two phases, concurrent with the bioventing pilot test activities described in Section 1.1. The initial phase will consist of bioventing system expansion and startup. An additional VW and MP will be installed, and an upgraded blower system will be installed for air injection into the existing VW, a new VW, and an existing monitoring well (MW). The blower will be conservatively sized so that additional VWs can be installed and plumbed to the system in the future, if necessary. The system will be started and optimized. During the second phase, the expanded system will be operated and monitored for a 1-year period. *In situ* respiration testing and soil gas sampling will

be performed at the end of the period to determine the degree of cleanup that was achieved.

1.3 Preliminary Remediation Goals for Contaminants at Sites ST10 and ST12

Petroleum hydrocarbons within the vadose zone represent the primary contaminants of concern at Sites ST10, ST12-A, and ST12-B. Specifically, benzene, toluene, ethylbenzene, and xylenes (BTEX) represent the greatest risk due to their relatively high toxicity and mobility as compared with aliphatic and larger aromatic hydrocarbon compounds which may be present. Preliminary remediation goals, shown in Table 1.1, were set in accordance with recommended cleanup criteria from Table 5.1 of the *Technical Guidance Manual for Underground Storage Tank Closure and Release Response* (State of Hawaii, Department of Health, 1992). BTEX contaminants within the shallow unsaturated zone of Site ST12-A are expected to meet levels shown in Table 1.1 as a result of expanded bioventing. Pilot testing at Sites ST10 and ST12-B will assess the feasibility of meeting these levels via enhanced *in situ* biodegradation through bioventing.

1.4 Project Deliverables

A report will be prepared following completion of the initial phase of testing and system expansion at the three sites. This report will summarize the initial bioventing pilot test results at Sites ST10 and ST12-B, and will make specific recommendations for continued system operation and/or expansion. If the initial phase of testing at Sites ST10 and ST12-B proves bioventing to be an effective means of remediating soil contamination at one or both of these sites, pilot test data will be used to prepare a conceptual full-scale design and cost estimate, and to estimate the time required for site cleanup. An operation and maintenance (O&M) manual for the three systems and as-built drawings of the expanded system at ST12-A will be provided. At the end of the second testing phase, a letter report will be prepared to summarize long-term testing results at the three sites, and to make recommendations for future action at the sites.

1.5 Work Plan Outline

This document is divided into 9 sections, including this introduction, and 2 appendices. Sections 2 and 3 present background information and proposed bioventing pilot test activities at Sites ST10 and ST12-B, respectively. Section 4 addresses Site ST12-A providing background information, a summary of successful results from the previous bioventing pilot test, and a description of the proposed bioventing system expansion. Section 5 describes proposed procedures for handling investigation-derived waste (IDW), Section 6 presents Base support requirements, and Section 7 presents a proposed project schedule for the activities described in this work plan. Section 8 provides key points of contact at Hickam AFB, AFCEE, and Parsons ES; and Section 9 provides the references cited in this document. Appendices A and B contain existing geologic boring logs and relevant well construction diagrams for Sites ST12-B, and ST12-A, respectively.

TABLE 1.1
PRELIMINARY REMEDIATION GOALS
FOR
SITES ST10, ST12-A, AND ST12-B
HICKAM AFB, HAWAII

Constituent	Soil Concentration (in parts per million)
Benzene	0.05
Toluene	7.0
Ethylbenzene	10.0
Xylenes	100.0

Reference: Table 5.1 (State of Hawaii, Department of Health, 1992).

Note: Reference document does not provide a cleanup criteria for xylenes. The level provided for xylenes was determined using the same methodology used by the State of Hawaii, Department of Health to determine the levels for benzene, toluene, and ethylbenzene (i.e. 10 times the maximum contaminant level (MCL) in drinking water).

Additional background information on the development and recent success of bioventing technology is found in the protocol document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et al., 1992). This protocol document will serve as the primary reference for pilot test well designs and the detailed procedures to be used during bioventing pilot testing.

2.0 SITE ST10 (VALVE PIT 17)

This section provides background information on Site ST10, including a site description and results of a recent soil gas survey, and a description of proposed bioventing pilot test activities for the site.

2.1 Site Description

2.1.1 History of Site ST10

Valve Pit 17 is located on the inactive Hickam POL pipeline in Kipapa Valley, approximately 2,000 feet southwest of Kipapa FSA. Valve Pit 17 is a subsurface vault where the Kipapa branch of the Hickam POL pipeline joins the Waikakalaua line (Figure 2.1). Site ST10 is located at Valve Pit 17.

Site ST10 is also designated as Leak Area 9 in previous reports. To date, two monitoring wells have been installed near Valve Pit 17. ST10MW01 was installed by Harding Lawson Associates (HLA) in 1991, and ST10MW02 was installed by Parsons ES in December 1992.

2.1.2 Geology and Hydrology at Site ST10

Because bioventing technology is applied to unsaturated soils, this section primarily discusses soils above the water table. Shallow deposits underlying the Valve Pit 17 area consist of alluvial sediments including clays, silts, and basalt cobbles and boulders. A shallow water-bearing zone is encountered at depths ranging from approximately 25 to 35 feet bgs. This zone is hydraulically connected to the Kipapa Stream which is located approximately 300 feet east of Valve Pit 17. Water from Kipapa Stream migrates laterally from the stream bed into the unconsolidated alluvium. The occurrence of the shallow water-bearing zone is sporadic and discontinuous, due to variation in permeabilities of the unconsolidated materials. During periods of high rainfall, Kipapa Stream rises and provides recharge to the shallow water-bearing zone, generally resulting in increased water levels in the monitoring wells. Conversely, during dry periods, the water levels tend to decrease in the monitoring wells. A geologic cross-section of Site ST10 is provided in Section 2.3.

2.1.3 Contaminants at Site ST10

Soils at Site ST10 have been impacted by petroleum hydrocarbons through potential leakage of the product piping and documented spills. A large accidental release of fuel (approximately 15,000 gallons of AVGAS) from Valve Pit 17 occurred in either 1957 or 1958 (ES, 1984). While the extent of contamination at Site ST10 is not currently

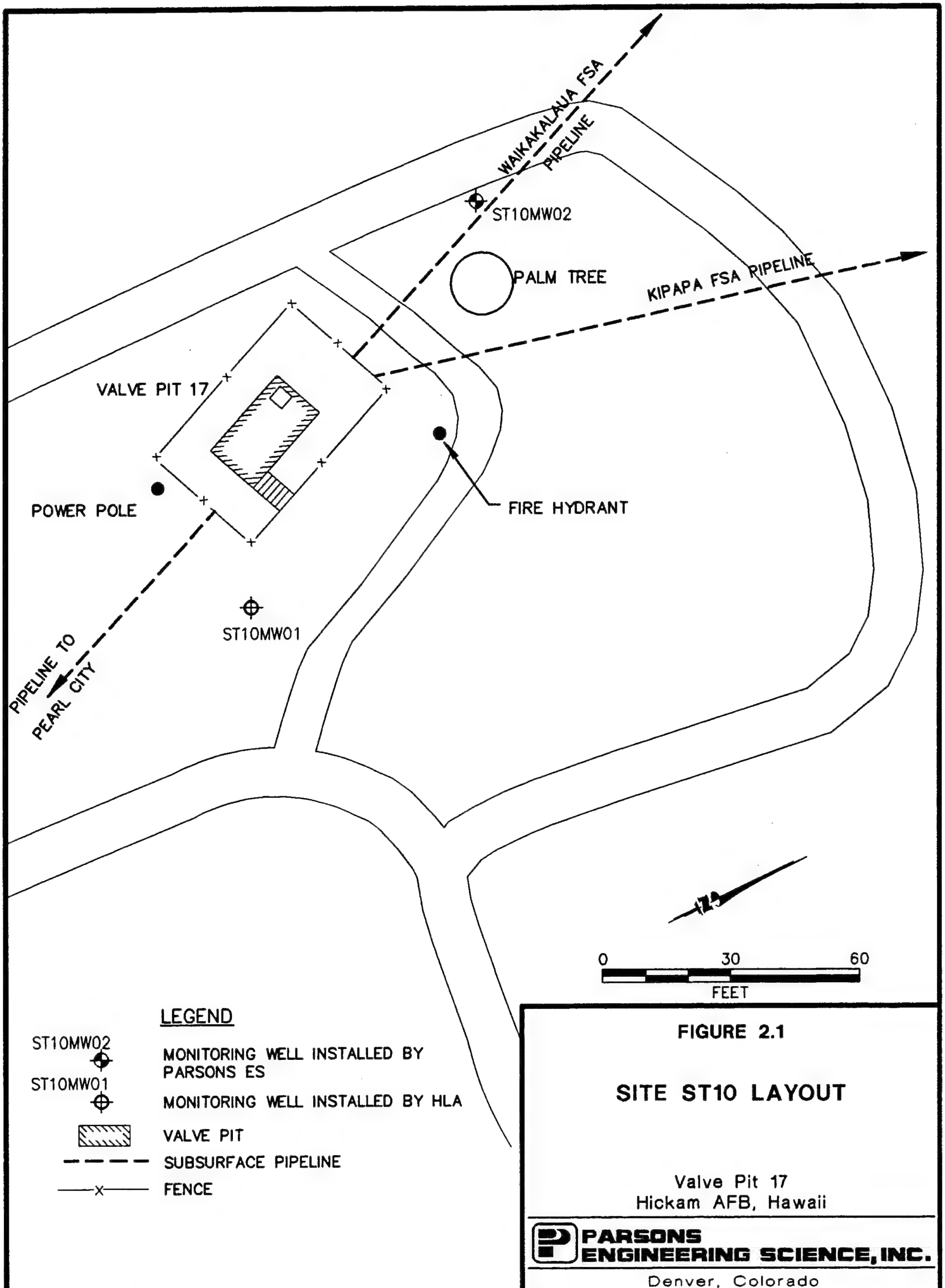

FIGURE 2.1

SITE ST10 LAYOUT

Valve Pit 17
Hickam AFB, Hawaii

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Denver, Colorado

known, petroleum hydrocarbons, especially BTEX contaminants, are thought to be the primary contaminants of concern. Table 2.1 provides soil and groundwater data for Site ST10.

During construction of monitoring well ST10MW02, soils appeared to be fuel-contaminated at depths from 6 to 25 feet below ground surface (bgs) based on photoinonization detector (PID) field screening. Groundwater samples collected from monitoring well ST10MW02 have shown varying concentrations of petroleum hydrocarbons; and a "smear zone" of petroleum hydrocarbon contamination is suspected to exist above the surface of the perched water zone at Site ST10.

2.2 Previous Bioventing Test Results at Site ST10

An initial soil gas survey for proposed bioventing activities was conducted at Site ST10 on June 6, 1995. The soil gas survey was performed to collect preliminary information regarding the extent of contamination and the feasibility of bioventing at this site.

Bioventing is expected to be a feasible technology for soil remediation at Site ST10, based on the results of initial soil gas sampling provided in Table 2.2. A soil gas sample collected from monitoring well ST10MW02 contained oxygen at a concentration of only 2 percent, indicating that aerobic biodegradation of petroleum hydrocarbons is occurring in unsaturated soils at this site. Although an elevated oxygen concentration was present in the soil gas sample collected from monitoring well ST10MW01, "smear zone" soils slightly above the depth of the perched water table are expected to be anaerobic. Monitoring well ST10MW01 is screened through both shallow clean soil and deeper contaminated soil. The oxygen detected in the soil gas sample is believed to originate from the shallow soil, masking low oxygen concentrations in the deeper soils.

2.3 Proposed Bioventing Pilot Test Activities at Site ST10

Pilot tests to determine the effectiveness of *in situ* bioventing for remediating petroleum contamination in unsaturated zone soils are planned for Sites ST10 and ST12-B. This section provides information regarding activities for Site ST10, to include, the proposed locations and construction details for the VWs and MPs, the blower system to be used for air extraction/injection into contaminated soils, and a brief description of the pilot test procedures. Section 3.3 addresses pilot test activities planned for Site ST12-B.

2.3.1 Layout of Pilot Test Components

Figure 2.2, a proposed site layout, and Figure 2.3, a geologic cross-section, illustrate the intended locations of the VWs, MPs, and blower system at Site ST10. Soils at the two proposed VW locations are expected to be contaminated with petroleum hydrocarbons and oxygen-depleted (< 2 percent); therefore, biological activity should be stimulated by aeration with oxygen-rich soil gas during pilot test operations. A review of the construction details for wells ST10MW01 and ST10MW02 indicated that they are suitable for use as VWs for air injection. The proposed locations for VW-1

TABLE 2.1
CONTAMINANTS OF CONCERN AT SITE ST10
VALVE PIT 17
HICKAM AFB, HAWAII

Sampling Location	Depth (ft bgs)[a]	Reference	TRPH[b] (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (mg/kg)
			Soil Hydrocarbons				
ST10MW02	7	Parsons ES[c]	<30[d]	<0.005	0.002	<0.005	<0.005
ST10MW02	13	Parsons ES	<30	<0.005	0.003	<0.005	<0.005
ST10MW02	27	Parsons ES	<30	<0.65	<0.9	5.7[e]	0.757[e]

Groundwater Hydrocarbons

Location-Sample No.	Dates Sampled	Reference	TRPH (mg/L)[f]	Benzene (ug/L)[g]	Toluene (ug/L)	Ethylbenzene (ug/L)	Xylenes (ug/L)
HPOL-ST10-MW02-1	12/92	Parsons ES	6	710	<188.7	850	NR[h]
HPOL-ST10-MW02-2	12/93	Parsons ES	6,600	3,720	<540.5	<500	4,130

a/ Sample depth in feet below ground surface.
b/ TRPH = total recoverable petroleum hydrocarbons analyzed by EPA Method 418.1; mg/kg = milligrams per kilogram.
c/ Parsons Engineering Science, Inc., 1995.
d/ "<" denotes sample result is less than laboratory method detection limit.
e/ The analyte was detected in the sample; however, the associated number is an estimated value because quality control criteria were not met.
f/ mg/L = milligrams per liter.
g/ ug/L = micrograms per liter.
h/ NR = Not reported.

TABLE 2.2
SOIL GAS CHEMISTRY AT SITE ST10
JUNE 6, 1995 SURVEY
HICKAM AFB, HAWAII

Monitoring Point	Screened Interval [a] (feet bgs)	Pressure (" H_2O)	O_2 (percent)	CO_2 (percent)	TVH [b] (ppmv)
SITE ST10 [c]					
ST10MW01	18-33	0.08	13	4.5	18,000
ST10MW02	18-34	0	2.0	5.5	5,000

[a] Designates screened interval and its depth below ground surface in feet.
[b] TVH=total volatile hydrocarbons; ppmv = parts per million, volume per volume.
[c] Site measurements were taken under static conditions.

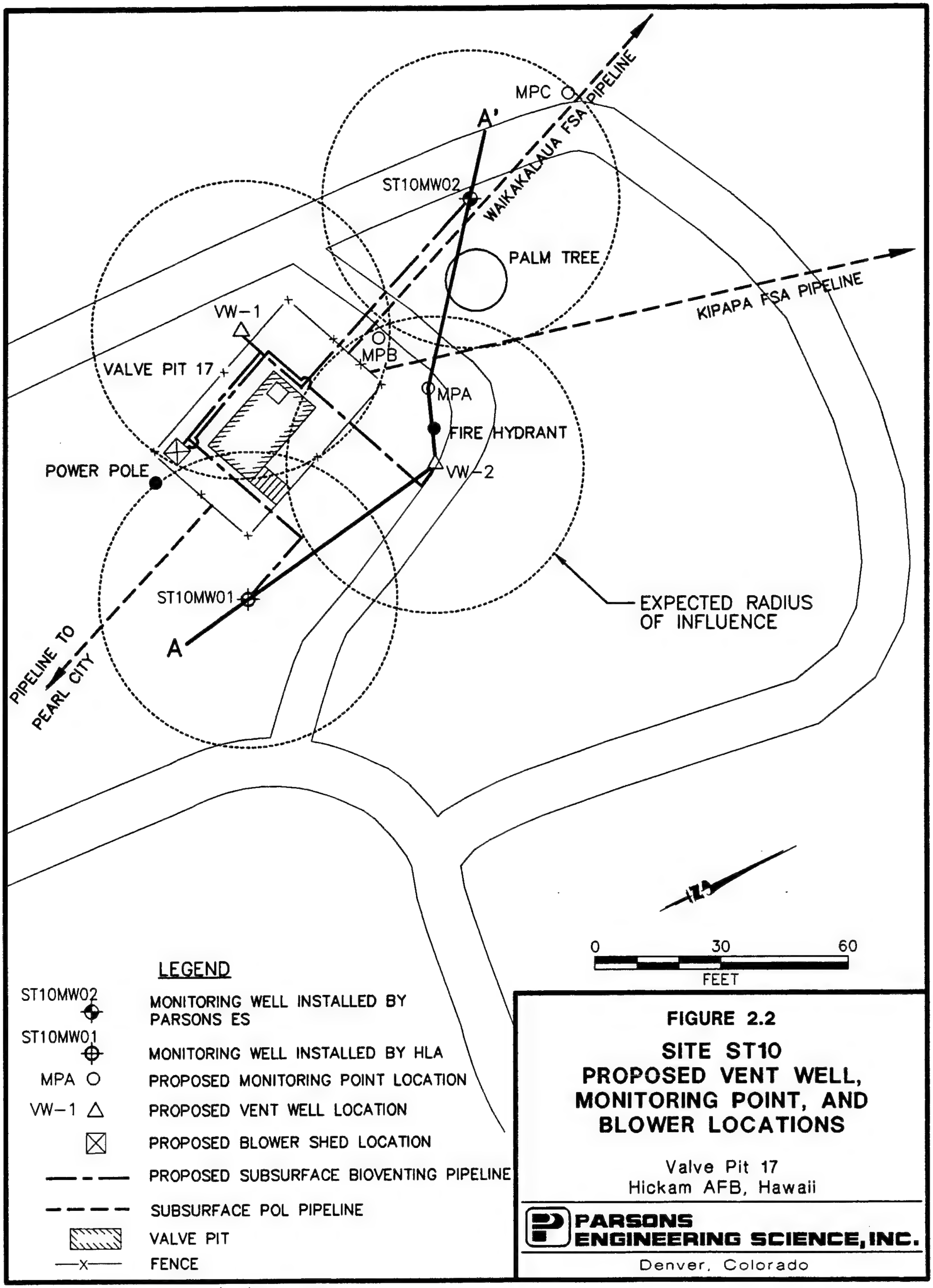

FIGURE 2.2

SITE ST10
PROPOSED VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS

Valve Pit 17
Hickam AFB, Hawaii

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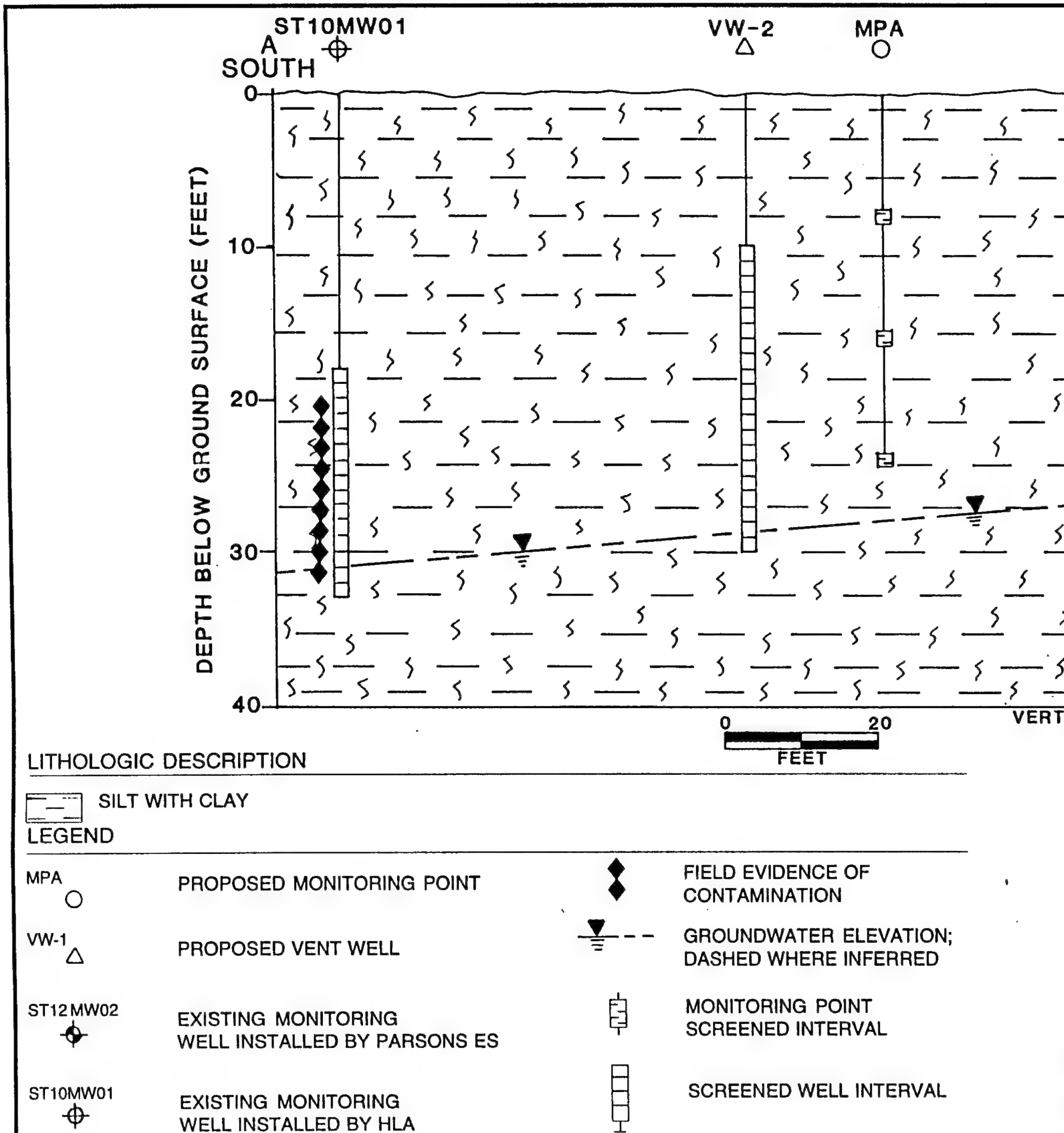

FIGURE 2.3

SITE ST10
GEOLOGIC CROSS-SECTION

Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

and VW-2 will maximize the extent of contaminated soil that can be oxygenated at Site ST10, assuming that in addition to VW-1, ST10MW01 and ST10MW02 can be used for air injection. To avoid creation of a stagnant zone between the VWs and MWs, soil gas will be extracted from VW-2, mixed with atmospheric air, and reinjected into VW-1 and the MWs. This set-up should enhance the flow of oxygenated soil gas beneath the valve pit, and eliminate issues regarding atmospheric emission of soil vapor. However, the proposed VW locations are located on private property, and Hickam AFB must obtain an access agreement with the property owner before drilling activities occur (Hickam AFB has an easement that runs parallel to the pipelines approximately 5 feet from the outer edge of the pipe). Based on previous pilot testing experience at Site ST12-A (ES, 1993a) and the Kipapa FSA (ES, 1994), the radius of venting influence around a single VW at Site ST10 is expected to be 30 to 40 feet.

2.3.2 Vent Well Installations

The two VWs will be constructed of 4-inch-diameter, Schedule 40 polyvinyl chloride (PVC) pipe. The screened intervals (0.04-inch slotted screen) are estimated to be set between 10 and 30 feet bgs. Final placement of the screened interval will be determined in the field depending on contamination encountered during installation activities. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded, No. 6-9 silica sand placed in the annular space from the bottom of the borehole to at least 2 feet above the screened interval. A bentonite seal will be placed directly over the filter pack to produce an air-tight seal above the screened interval. The bentonite seal will be placed in 1-foot layers, with each layer hydrated in place with potable water prior to the addition of subsequent layers. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. The VW surface completion will consist of a 12-inch diameter, flush-mounted, protective well box emplaced in a concrete pad. Figure 2.4 illustrates the proposed VW construction details for Site ST10.

2.3.3 Monitoring Point Installations

Proposed multi-depth vapor MP installations for Site ST10 are shown on Figure 2.5. Soil gas oxygen, carbon dioxide, and TVH concentrations will be monitored at screened depths at each MP. Soil temperatures will be monitored using thermocouples installed in the shallow and deep screened intervals of MPA. Multi-depth monitoring will confirm whether the entire soil profile is receiving oxygen, and will allow fuel biodegradation rates to be measured at three separate depths.

Each MP will be constructed with three vapor probes placed within a No. 6-9 silica sand pack, separated by bentonite seals. Each vapor probe will be constructed of 6-inch-long sections of 1-inch-diameter PVC well screen. The final placement of the vapor probes will be determined based on site conditions encountered during installation activities. The bentonite will be placed in 1-foot layers and hydrated with potable water prior to placement of subsequent layers to ensure complete saturation of the bentonite. Additional details on VW and MP construction are presented in Section 4 of the protocol document (Hinchee *et al.*, 1992).

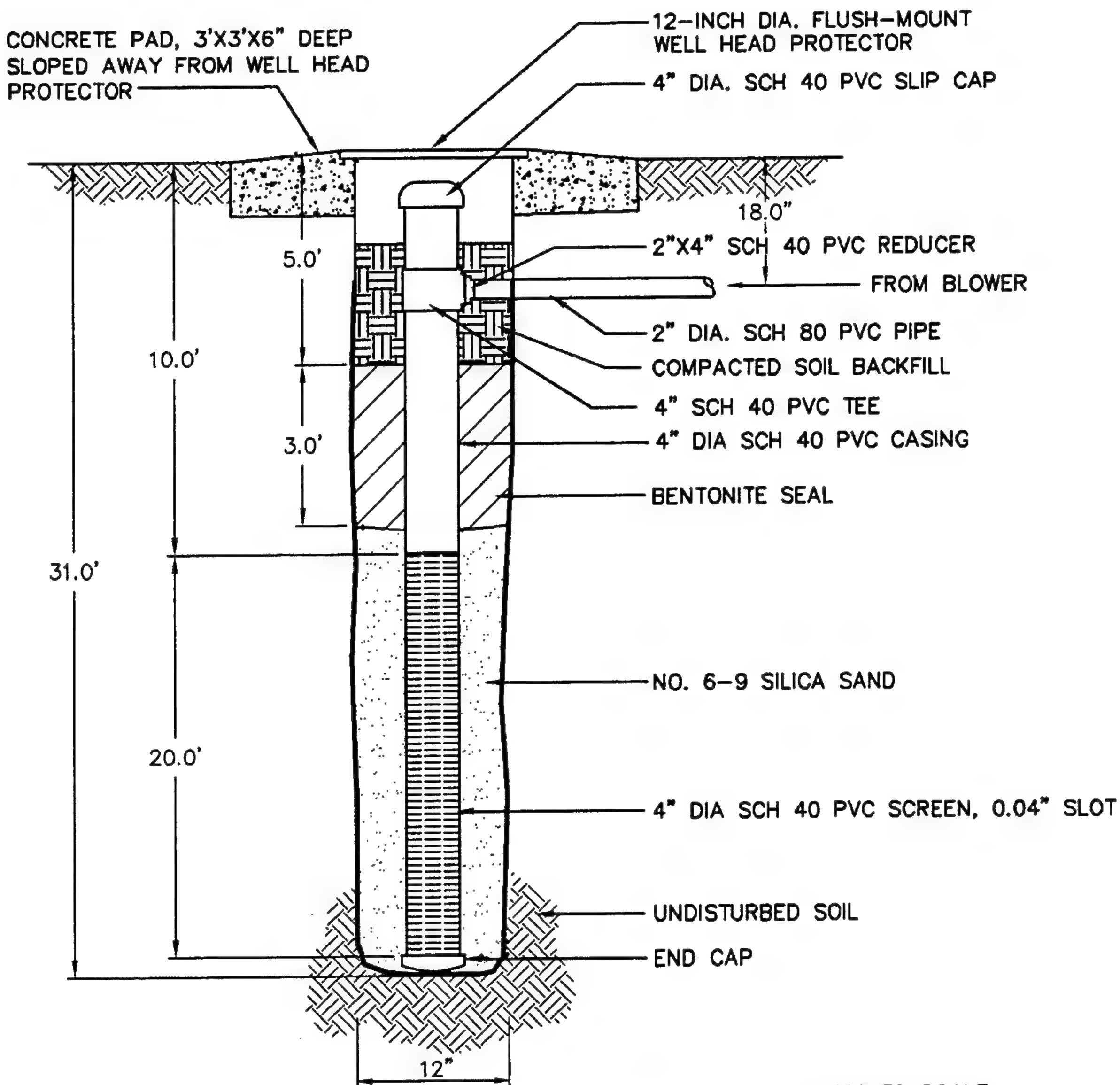

FIGURE 2.4

SITE ST10 PROPOSED INJECTION VENT WELL CONSTRUCTION DETAIL

Valve Pit 17
Hickam AFB, Hawaii

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

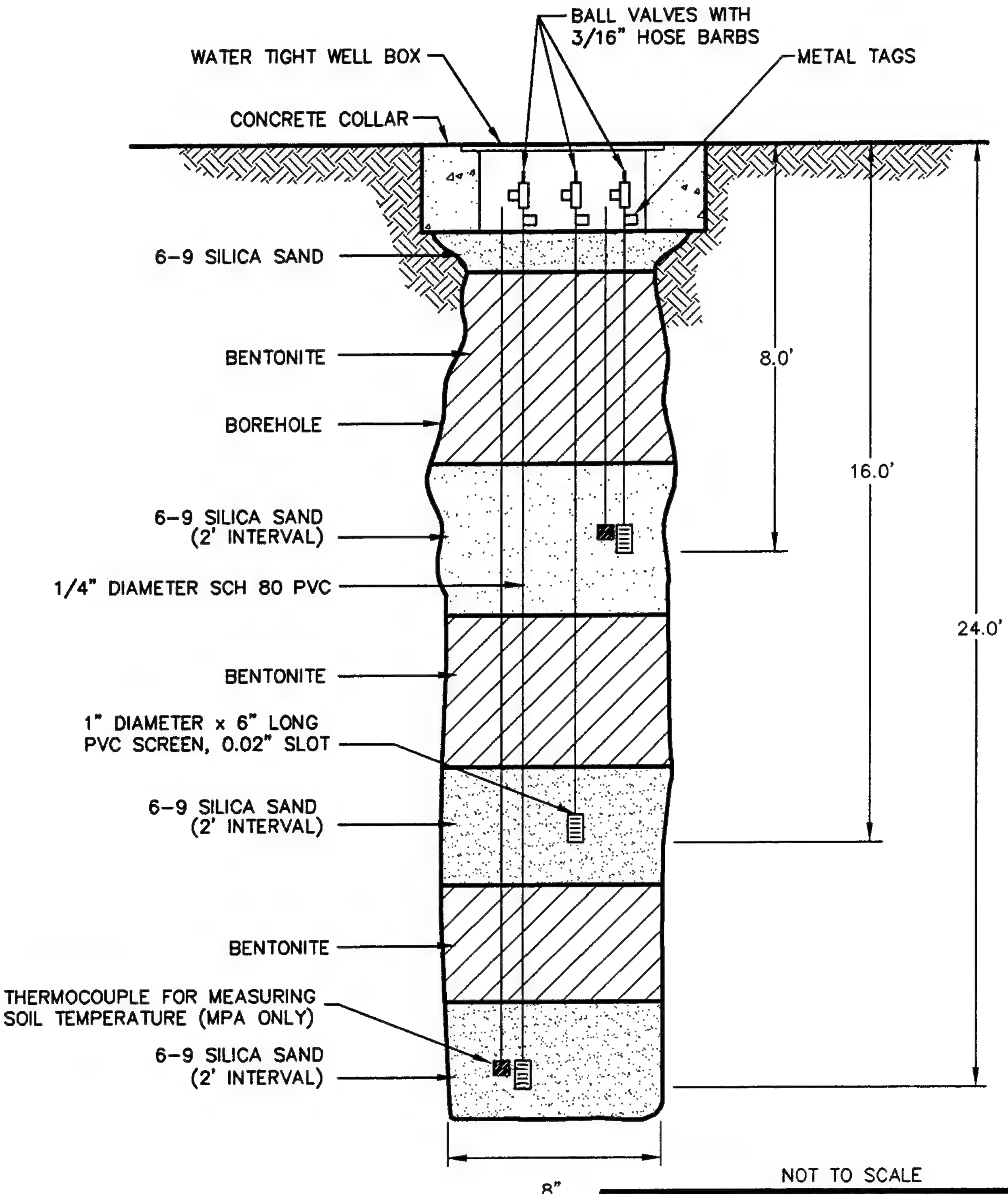

FIGURE 2.5

**SITE ST10
PROPOSED
MONITORING POINT
CONSTRUCTION DETAIL**

Valve Pit 17
Hickam AFB, Hawaii

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2.3.4 Background Monitoring Points

Background MPs are required to measure background levels of oxygen and carbon dioxide in unimpacted soils to determine if natural carbon sources are contributing to oxygen uptake during *in situ* respiration testing. Existing background monitoring point ST01-BG, installed during previous pilot testing efforts at Kipapa FSA (Site ST01), will be used during the pilot test since soils at Site ST01 are similar to those at Site ST10.

2.3.5 Soil and Soil Gas Sampling

2.3.5.1 Soil Samples

Six soil samples will be collected from the pilot test area during installation of the VWs and MPs. These soil samples will be submitted to a certified laboratory for analyses. Sampling procedures will follow those outlined in the protocol document (Hinchee *et al.*, 1992). A TVH vapor analyzer will be used during drilling to screen split-spoon samples for intervals of high fuel contamination. Split-spoon samples will be collected at 5-foot intervals. Based on field screening results, six samples from the most highly contaminated locations at the site will be analyzed for TRPH by US Environmental Protection Agency (EPA) Method 8015 (modified) and BTEX by EPA Method 8020. Three of the six samples obtained from the site will also be analyzed for soil moisture, pH, particle size, alkalinity, total iron, and nutrients.

Soil samples for laboratory analyses will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes for TRPH, BTEX, and physical parameter analyses will be immediately trimmed, and the ends will be sealed with aluminum foil or Teflon® fabric held in place by plastic caps. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5), wrapped in plastic, placed in a cooler with ice, and maintained at a temperature of 4 degrees centigrade (°C) for shipment. A chain-of-custody form will be completed, and the cooler will be shipped to a certified laboratory for analysis.

2.3.5.2 Soil Gas Samples

Soil gas samples will be collected from the VWs, MWs, and MPs and field-screened for oxygen, carbon dioxide, and TVH. Soil gas samples from the six most contaminated locations at the site will be collected in SUMMA® canisters in accordance with the Bioventing Field Sampling Plan (ES, 1992) and submitted for laboratory analysis. These soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and TVH during the 1-year tests, and to detect any migration of these vapors from the source areas.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will be sent at ambient temperature to prevent condensation of hydrocarbons. A chain-of-custody form will be completed, and the cooler will be shipped to the Air Toxics, Inc. laboratory in Folsom, California for BTEX and TPH analysis by EPA Method TO-3.

2.3.6 Blower System

A 2.5-horsepower regenerative blower capable of injecting air over a wide range of flow rates and pressures will be used to conduct the initial pilot test and extended pilot testing at Site ST10. Figure 2.6 presents a general schematic of the air injection system to be used for pilot testing at Sites ST10 and ST12-B. The maximum power requirement anticipated for the pilot test is 240-volt, single-phase, 30-amp service. Electrical power will be obtained from the existing power pole located adjacent to Valve Pit 17 (Figure 2.2). Installation of electrical equipment, buried electrical conduits, and necessary wiring will be provided by an electrical subcontractor hired by Parsons ES.

2.3.7 *In Situ* Respiration Tests

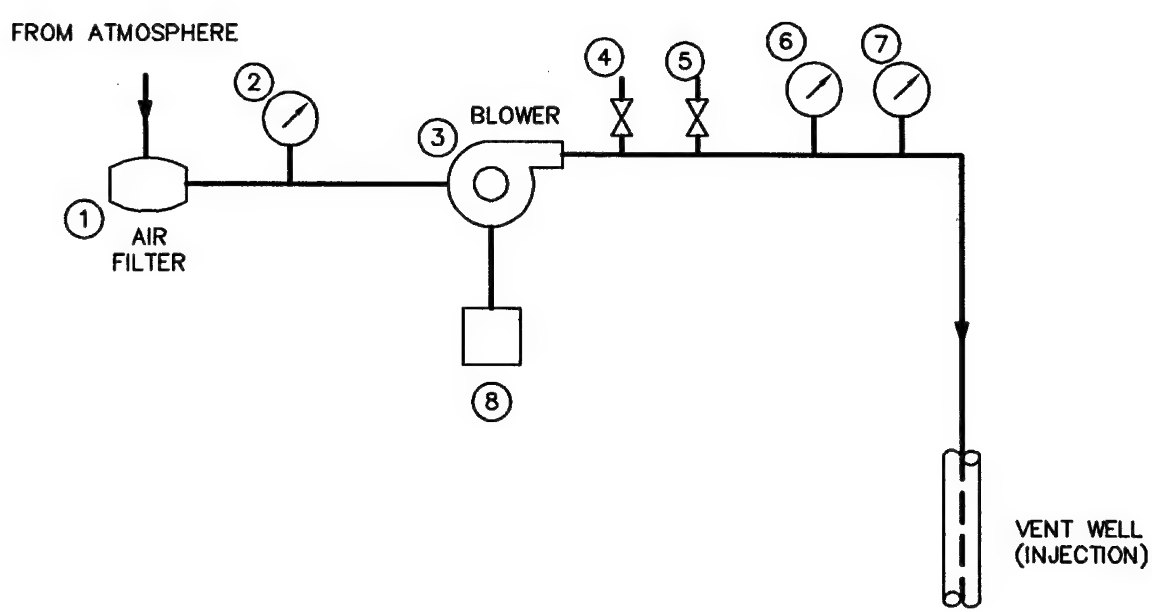
The objective of *in situ* respiration testing is to determine the rate at which soil bacteria degrade petroleum hydrocarbons at the site. Respiration tests will be performed at selected MPs where bacterial biodegradation of hydrocarbons is indicated by low oxygen levels and elevated carbon dioxide concentrations in the soil gas. Using 1-cubic feet per minute (cfm) pumps, air will be injected into approximately four MP depth intervals containing low levels (< 2 percent) of oxygen. A 20-hour air injection period will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off, and oxygen, carbon dioxide, and TVH concentrations will be monitored during the following 48 to 72 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium, an inert gas, will also be injected into the selected MP screened intervals to assess the extent of soil gas diffusion and to determine the effectiveness of the MP bentonite seals. Additional details on the *in situ* respiration test are found in Section 5.7 of the protocol document (Hinchee et al., 1992).

2.3.8 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection VW. Prior to initiating the tests, baseline concentrations of oxygen, carbon dioxide, and TVH will be measured in soil gas from the VWs, MWs, and each MP screened interval.

Air will be injected into VW-2 using the blower unit, and pressure response will be measured at each MP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored at the MPs to ascertain whether oxygen levels in the soil gas increase as the result of air injection. The air permeability test will last between 4 and 24 hours depending on the "tightness" of soils at ST10.

Ambient air quality monitoring will be conducted during the air permeability test to determine if air injection into the soil will displace volatile organic compounds (VOCs) into the atmosphere. Air quality monitoring will be conducted using a PID with a detection limit of 1 ppmv. Monitoring will be conducted across the pilot testing area on an hourly basis, at a minimum, during the first four hours of the air permeability



LEGEND

1. INLET AIR FILTER
2. VACUUM GAUGE
3. BLOWER – GAST® 2.5HP R5125Q–50
4. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. TEMPERATURE GAUGE
7. PRESSURE GAUGE
8. DISCONNECT SWITCH

FIGURE 2.6

SITES ST10 AND ST12-B PROPOSED BLOWER INSTRUMENTATION DIAGRAM FOR PILOT TESTING

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test. If VOCs are detected in ambient air at concentrations exceeding safety thresholds, the test will be discontinued. If VOCs are detected at lower concentrations, monitoring will continue until the detections dissipate. If VOCs persist in ambient air, corrective action (i.e. decreasing the air injection flow rate, identifying and blocking preferential flow channels to the surface) will be taken. If these corrective actions are performed and VOCs still persist in ambient air, the test will be discontinued and an alternative remedial approach will be recommended to Hickam AFB. Past experience at other Hickam AFB bioventing sites has shown that VOCs are rarely driven into the atmosphere at detectable concentrations during bioventing operations.

2.3.9 Installation of 1-Year Pilot-Scale Bioventing System

The pilot-scale bioventing system to be installed at Site ST10 will be in operation for a 1-year period. It is anticipated that the blower will extract air from VW-2 and inject air into VW-1 and the two MWs at approximately 25 standard cubic feet per minute (scfm) per well. The VWs and MWs will be manifolded to the blower unit at Site ST10 as shown on Figure 2.2. The blower will be housed in small, lockable, prefabricated shed to provide protection from the weather. The blower unit will be explosion-proof, and electrical wiring will be installed in accordance with the National Electric Code (NEC) and Base codes for locations with potentially explosive atmospheres.

The system will be in operation for 1 year. System checks will be performed by Hickam AFB personnel once every two weeks. If required, major maintenance of the blower unit will be performed by Parsons ES personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual that will be provided to the Base. After the system has operated for 1 year, Parsons ES personnel will return to the site to conduct *in situ* respiration testing and soil gas sampling to determine the long-term effectiveness of the system.

3.0 SITE ST12-B (WAIKAKALAUA FUEL STORAGE ANNEX)

This section provides information on Site ST12-B. Its format is similar to the previous section on ST10, providing site specific information and a description of proposed bioventing pilot test activities for the site.

3.1 Site Description

As shown in Figure 3.1, Site ST12-B is located near the southern boundary of Waikakalaua FSA. Waikakalaua FSA (Site ST12) is a former fuel handling and storage facility occupying 34 acres of property located approximately 2 miles south of Wheeler Army Air Field. Site ST12 contains nine underground storage tanks (USTs) with a fuel storage capacity of 1.75 million gallons each. The facility operated as the northern terminus of the Hickam POL system from May 1943 until April 1993, when the facility was decommissioned.

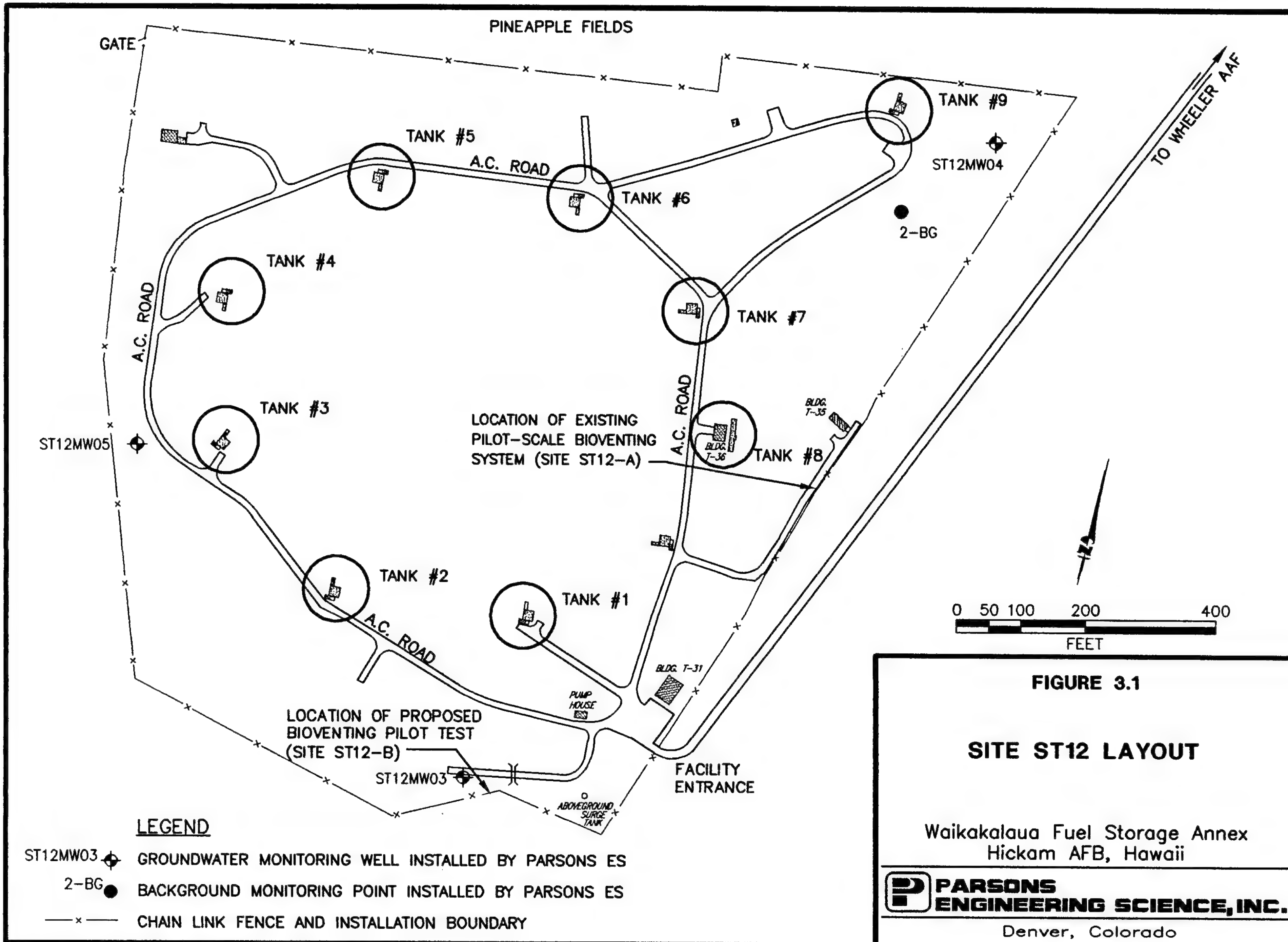

FIGURE 3.1

SITE ST12 LAYOUT

Waikakalaua Fuel Storage Annex
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3.1.1 History of Site ST12-B

Figure 3.2 shows the layout of Site ST12-B. Similar to Site ST12-A located to the northeast, an open-bottomed drywell at the site was formerly used for the disposal of waste petroleum hydrocarbons. The drywells located at Sites ST12-A and ST12-B are suspected to be the primary sources of petroleum hydrocarbon contamination in the subsurface at Waikakalaua FSA. Monitoring well MW-7 at Site ST12-B was installed in 1988 during the first subsurface investigation at Site ST12 (HLA, 1992). Parsons ES installed ST12MW03, a groundwater monitoring well, at the site in the spring of 1993 (Parsons ES, 1995). In previous reports, the Waikakalaua FSA was designated as Site 2.

3.1.2 Geology and Hydrology at Site ST12-B

In general, shallow deposits at the Waikakalaua FSA consist of unconsolidated fill and colluvium (clay and silt) overlying a layer of saprolite (weathered basalt). Beneath the saprolite, bedrock consists of layered basalt flows of varying thickness, with occasional saprolitic zones between flows. The basalt and saprolite are generally heavily fractured, with some more competent layers or zones that may act as local aquitards. At Site ST12-B, the fill and colluvium extend to a depth of 80 feet bgs, and the saprolite layer extends from 80 to 110 feet bgs. Basalt occurs at 110 feet bgs. Geologic boring logs for MW-7 and ST12MW03 and construction details of MW-7 are included in Appendix A.

The Pearl Harbor basal aquifer underlies Site ST12. The water table surface of the basal aquifer is located between approximately 650 and 730 feet bgs. Regional groundwater flow is to the south/southeast, toward Pearl Harbor. However, groundwater elevation data collected by Parsons ES from the three groundwater monitoring wells at Site ST12 (Figure 3.1) between November 1993 and March 1994 indicate that basal groundwater flow beneath Waikakalaua FSA could be toward the northwest. Based on the water level data, the gradient is approximately 0.003 feet per foot (ft/ft).

3.1.3 Contaminants at Site ST12-B

The primary contaminants at this site are petroleum hydrocarbons present in the unsaturated zone. Significant concentrations of petroleum contaminants have been detected near the drywell in soil samples from depths greater than 20 feet. This depth corresponds with the bottom of the concrete-lined drywell. Petroleum hydrocarbon contaminants have also been detected in groundwater beneath Site ST12-B. Table 3.1 summarizes available soil and groundwater sample data of petroleum hydrocarbon and BTEX contamination at the site.

Previous investigations at Site ST12-B included construction of two monitoring wells, MW-7 and ST12MW03. At MW-7, soils were impacted by petroleum hydrocarbons between depths of approximately 30 and 90 feet bgs, based on organic vapor analyzer (OVA) readings. A soil sample collected from a depth of 88 feet bgs during the installation of MW-7 in January and February 1988 yielded a TRPH

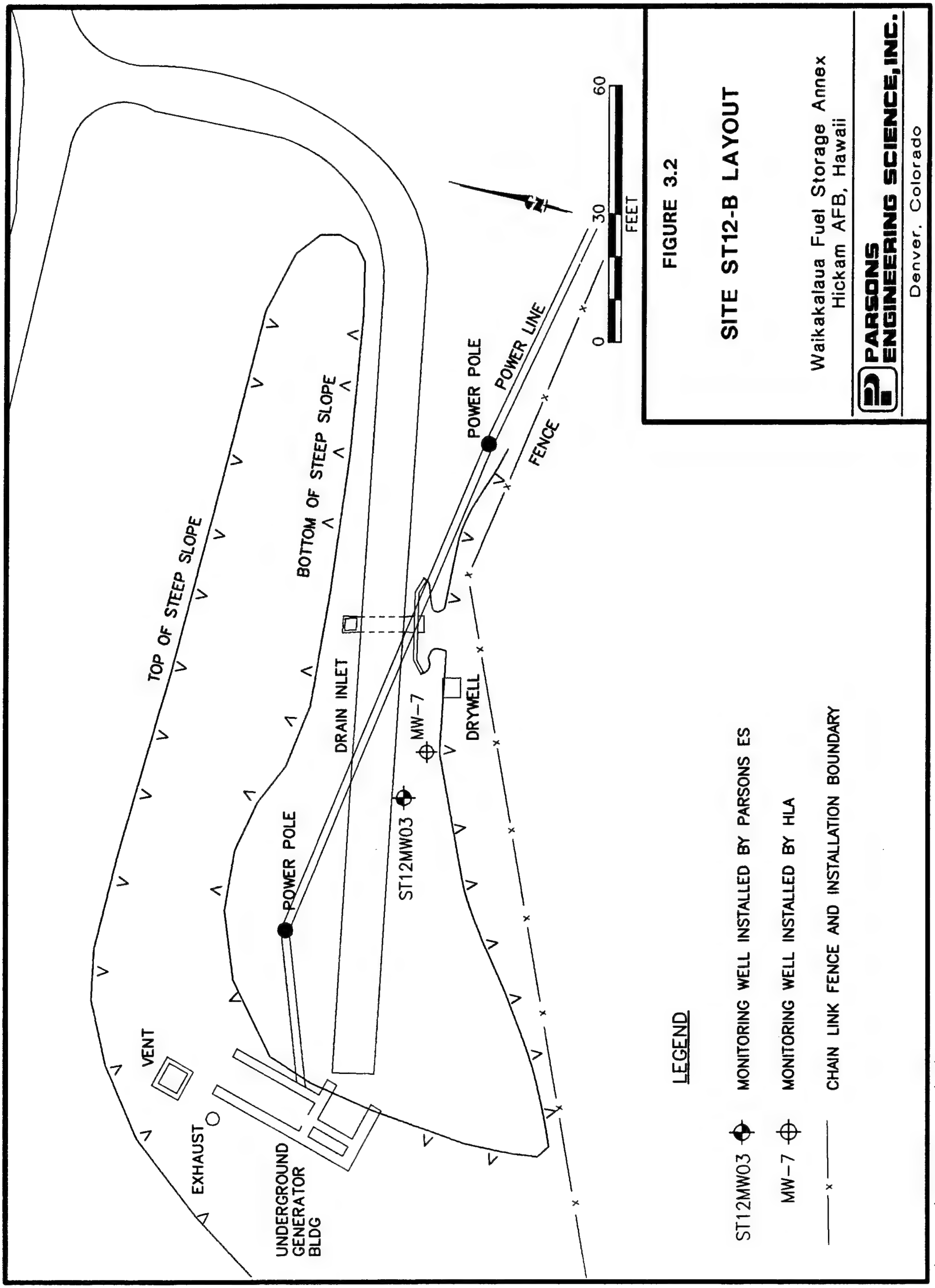

FIGURE 3.2

SITE ST12-B LAYOUT

Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

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TABLE 3.1
CONTAMINANTS OF CONCERN AT SITE ST12-B
WAIKAKALAUA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

Sampling Location	Depth (ft bgs)[a/]	Reference	TRPH[b/] (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (mg/kg)
			Soil Hydrocarbons				
MW-7	32	HLA[c/]	ND[d/]	NR[e/]	ND	ND	ND
MW-7	58	HLA	ND	NR	ND	ND	ND
MW-7	88	HLA	594	NR	ND	ND	ND
Boring 1	4	HLA	ND	NR	ND	ND	ND
Boring 1	16	HLA	ND	NR	ND	ND	ND
Boring 1	25	HLA	ND	NR	ND	ND	ND
ST12MW03	25	Parsons ES[f/]	11.0[g/]	<0.005[h/]	<0.005	<0.005	<0.005
ST12MW03	43	Parsons ES	<45.0	0.03	0.049	0.009	0.042
ST12MW03	74	Parsons ES	6.0[g/]	<0.005	0.003[g/]	<0.01	0.003
ST12MW03	92	Parsons ES	<45.0	0.013	0.018	<0.005	0.013

Groundwater Hydrocarbons

Sampling Location	Date	Reference	TRPH (ug/L)[i/]	Benzene (ug/L)	Toluene (ug/L)	Ethylbenzene (ug/L)	Xylenes (ug/L)
ST12MW03[j/]	7/16/93	Parsons ES	200	4.0	2.1	2.3	37.5
ST12MW03[j/]	1/20/94	Parsons ES	200[g/]	1.8	1.4	0.9[g/]	9.0
ST12MW03-PH[k/]	1/21/93	Parsons ES	NA[l/]	40	<18.87	16	NR

[a/] Sample depth in feet below ground surface.
[b/] TRPH = total recoverable petroleum hydrocarbons anayzed by EPA method 418.1; mg/kg = milligrams per kilogram.
[c/] Harding Lawson and Associates, 1992.
[d/] ND = Not detected (laboratory detection limit not available).
[e/] NR = Not reported.
[f/] Parsons Engineering Science, Inc., 1995.
[g/] The analyte was detected in the sample; however, the associated number is an estimated value because quality control criteria were not met.
[h/] "<" denotes sample result is less than laboratory detection limit.
[i/] ug/L = micrograms per liter.
[j/] Result averaged with duplicate.
[k/] Pilot hole drilled adjacent to STMW03 prior to drilling monitoring well.
[l/] NA = Not applicable.

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concentration of 594 mg/kg. In March 1993, during construction of groundwater monitoring well ST12MW03, soils were found to be contaminated at depths between 20 and 130 feet bgs, based on PID measurements. A groundwater sample collected at approximately 650 feet bgs from ST12MW03 yielded a total petroleum hydrocarbon (TPH) concentration of 200 micrograms per liter (ug/L).

3.2 Previous Bioventing Test Results at Site ST12-B

An initial soil gas survey for proposed bioventing activities was conducted at Site ST12-B on June 6, 1995. As was the case with Site ST10, the soil gas survey was performed to collect preliminary information regarding the extent of contamination and the feasibility of bioventing at the site. Soil gas survey results for Site ST12-B are presented in Table 3.2.

A soil gas sample collected from monitoring well MW-7 contained an elevated oxygen concentration (15.5 percent) and TVH were not detected, indicating that the basalt at this sampling location was not impacted by petroleum hydrocarbons at depths ranging from 135 to 155 feet bgs. Based on observations made during the installation of MW-7 and ST12MW03, and during bioventing pilot testing at nearby Site ST12-A, soils at shallower depths (in the saprolite and clay layers) are petroleum-impacted and are expected to be oxygen-depleted. Thus, the installation of a pilot-scale bioventing system at ST12-B should enhance the degradation of petroleum hydrocarbons in the clay and saprolite, and protect the underlying basalt from future petroleum hydrocarbon contamination.

3.3 Proposed Bioventing Pilot Test Activities at Site ST12-B

This section describes the bioventing pilot test activities proposed for Site ST12-B. The pilot test activities planned for Site ST12-B are generally the same as those previously discussed for Site ST10; however, bioventing system design varies somewhat between the two sites.

3.3.1 Layout of Pilot Test Components

The proposed site layout and a geologic cross-section of Site ST12-B are provided at Figures 3.3 and 3.4, respectively. Because the extent of hydrocarbon contamination has not yet been defined at the site, the proposed system layout is designed to maximize the area to be characterized. The VW location is set immediately adjacent to the drywell, the suspected source of petroleum hydrocarbon contamination. Soils at the VW are expected to be contaminated with petroleum hydrocarbons and oxygen depleted, and as a result, a good candidate for enhanced *in situ* biodegradation through bioventing. The MPs were placed in an attempt to surround the drywell in order to evaluate the extent and location of vadose zone contamination and the effectiveness of bioventing pilot test activities. Air injected into the VW should enhance natural biodegradation fuel contaminants in the saprolite and clay layers. The radius of venting influence at the VW is expected to be 30 to 35 feet. While initial soil gas survey results (presented in Table 3.2) indicate the basalt at 135 to 155 feet bgs is not currently impacted by petroleum hydrocarbons, groundwater beneath Site ST12-B was

TABLE 3.2
SOIL GAS CHEMISTRY AT SITE ST12-B
JUNE 6, 1995 SURVEY
HICKAM AFB, HAWAII

Monitoring Point	Screened Interval [a/] (feet bgs)	Pressure (" H_20)	O_2 (percent)	CO_2 (percent)	TVH [b/] (ppmv)
SITE ST12-B [c/]					
MW-7	134.5-155	0.4	15.5	2.8	0

[a/] Designates screened interval and its depth below ground surface in feet.
[b/] TVH=total volatile hydrocarbons; ppmv = parts per million, volume per volume.
[c/] Site measurements were taken under static conditions.

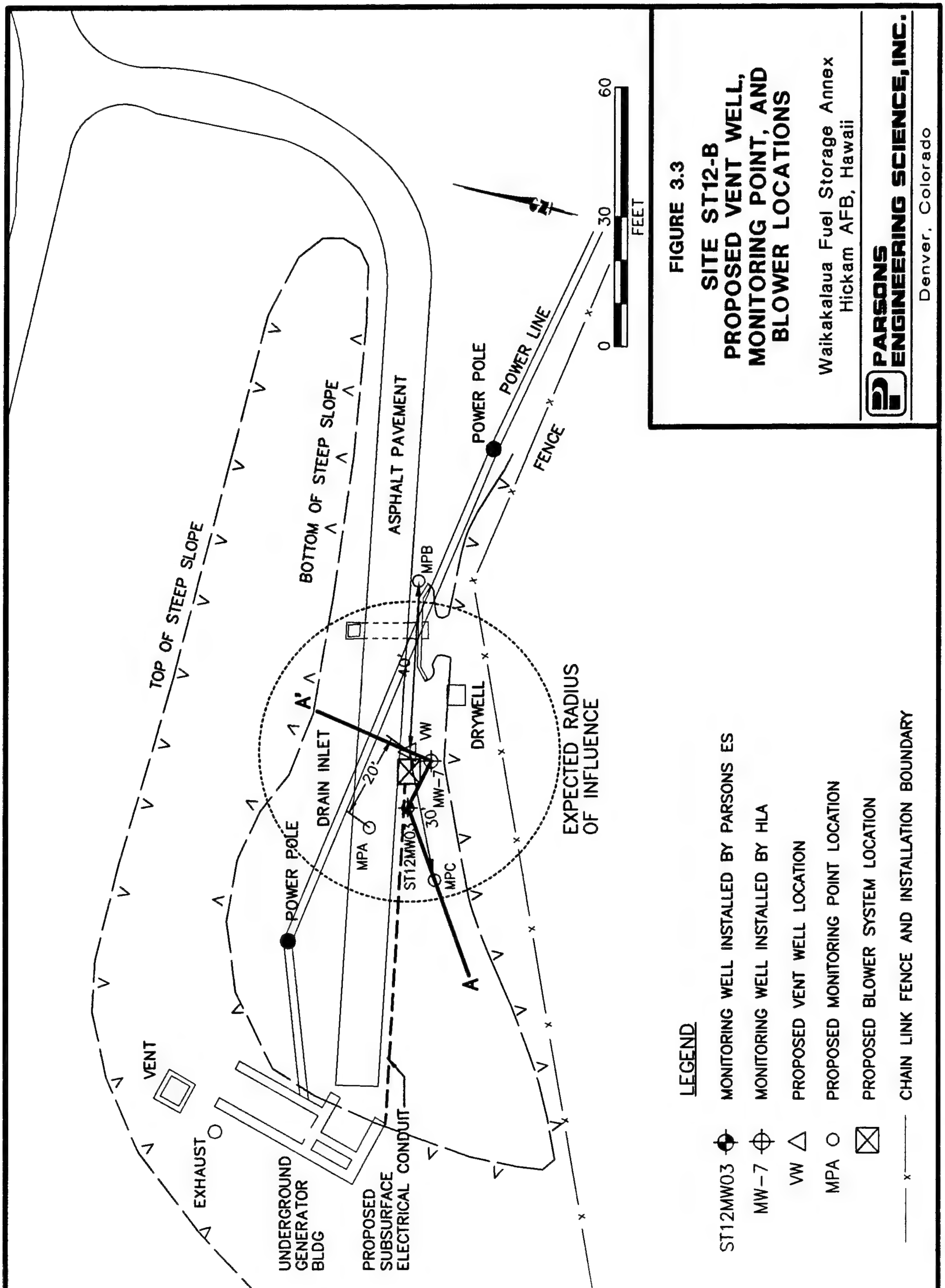

FIGURE 3.3
SITE ST12-B
PROPOSED VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS
Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

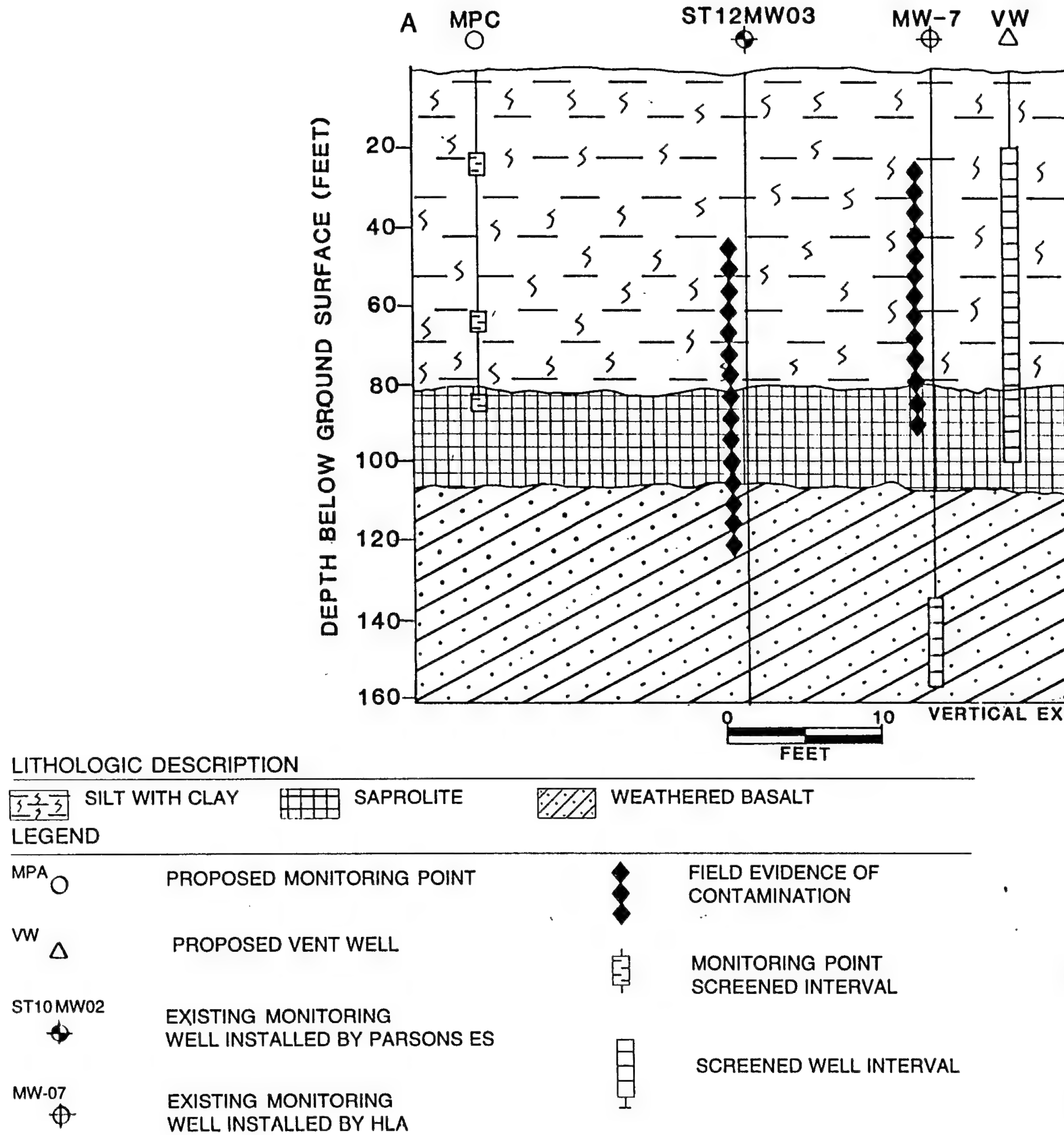

FIGURE 3.4

SITE ST12-B
GEOLOGIC CROSS-SECTION

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found to contain elevated TPH concentrations during the installation of ST12MW03. A manifold will be installed on the blower system and air will also be injected into MW-7 as a means of potentially remediating any fuel contamination which may exist in the basalt zone.

3.3.2 Vent Well Installations

The VW will be constructed of 4-inch-diameter Schedule 40 PVC pipe. The 0.04-inch slotted screened interval is estimated to be set between 20 and 100 feet bgs at Site ST12-B. Vent well construction at Site ST12-B will be similar to that described in Subsection 2.3.2. Figure 3.5 illustrates the proposed VW construction details for Site ST12-B.

3.3.3 Monitoring Point Installations

Proposed multi-depth vapor MP installations for Site ST12-B is shown on Figure 3.6. Soil gas oxygen, carbon dioxide, and TVH concentrations will be monitored at screened depths at each MP. Soil temperatures will be monitored using thermocouples installed in the shallow and deep screened intervals of MPA. Multi-depth monitoring will confirm whether the entire soil profile is receiving oxygen, and will allow fuel biodegradation rates to be measured at three separate depths. Monitoring point construction will resemble that previously described in Subsection 2.3.3.

3.3.4 Background Monitoring Points

Existing background monitoring point, 2-BG installed during previous pilot testing efforts at ST12 will be used during the pilot test. Soils at this MP are similar to those at ST12-B.

3.3.5 Soil and Soil Gas Sampling

3.3.5.1 Soil Samples

Soil samples at Site ST12-B will be collected in accordance with Subsection 2.3.5.1; however, split-spoon samples will be collected at 10 foot intervals for evaluation of subsurface fuel contamination.

3.3.5.2 Soil Gas Samples

Soil gas samples will be collected in accordance with Subsection 2.3.5.2.

3.3.6 Blower Systems

Similar to Site ST10, a 2.5-horsepower regenerative blower capable of injecting air over a wide range of flow rates and pressures will be used to conduct the initial pilot test at Site ST12-B (Figure 2.6); however, a 5-horsepower regenerative blower will be used for extended testing. The maximum power requirement anticipated for Site ST12-B pilot test is 480-volt three-phase, 20-amp service. Electrical power will be obtained from inside the Emergency Generator Building located at the site. Installation of

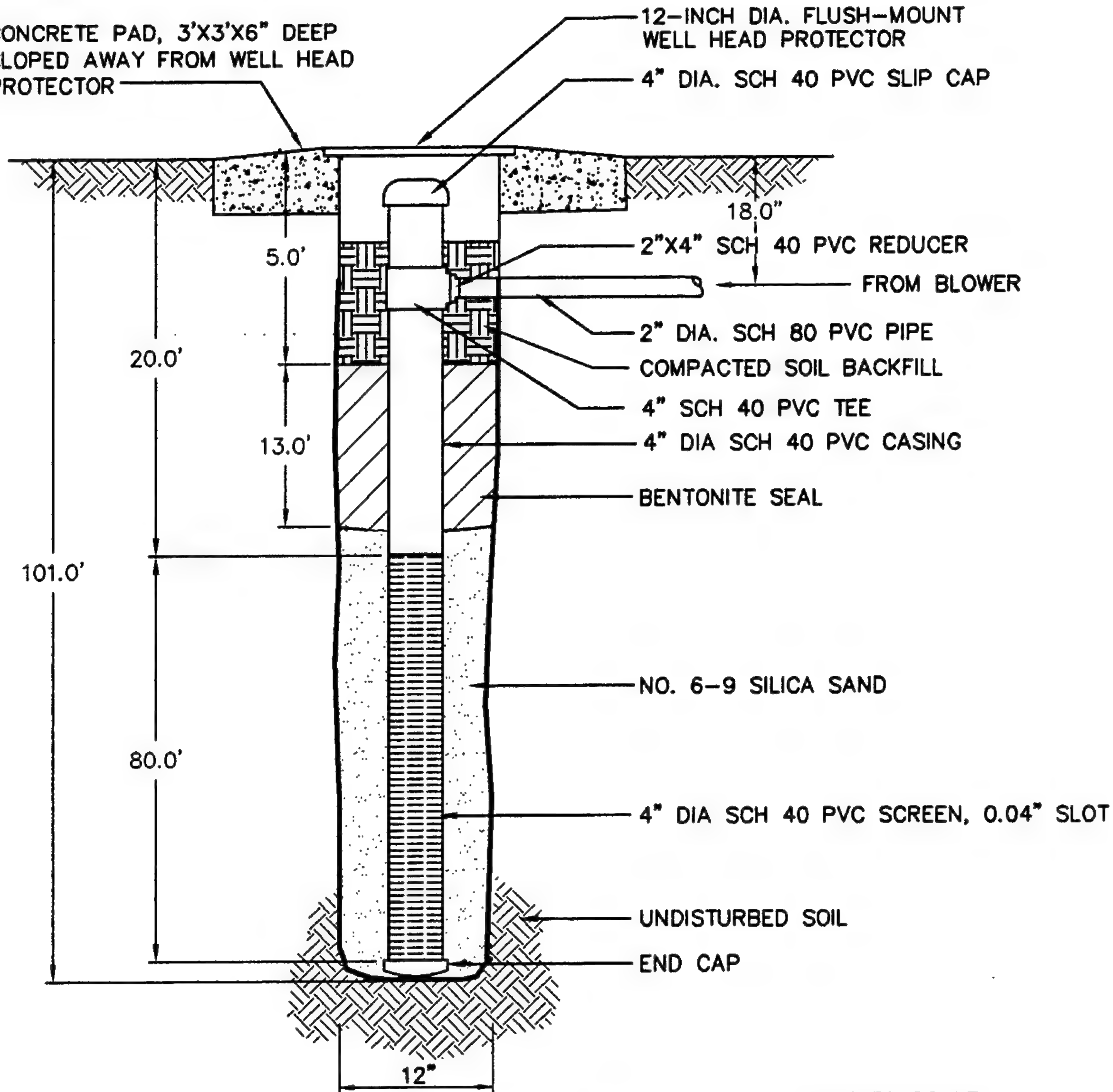

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FIGURE 3.5

SITE ST12-B PROPOSED INJECTION VENT WELL CONSTRUCTION DETAIL

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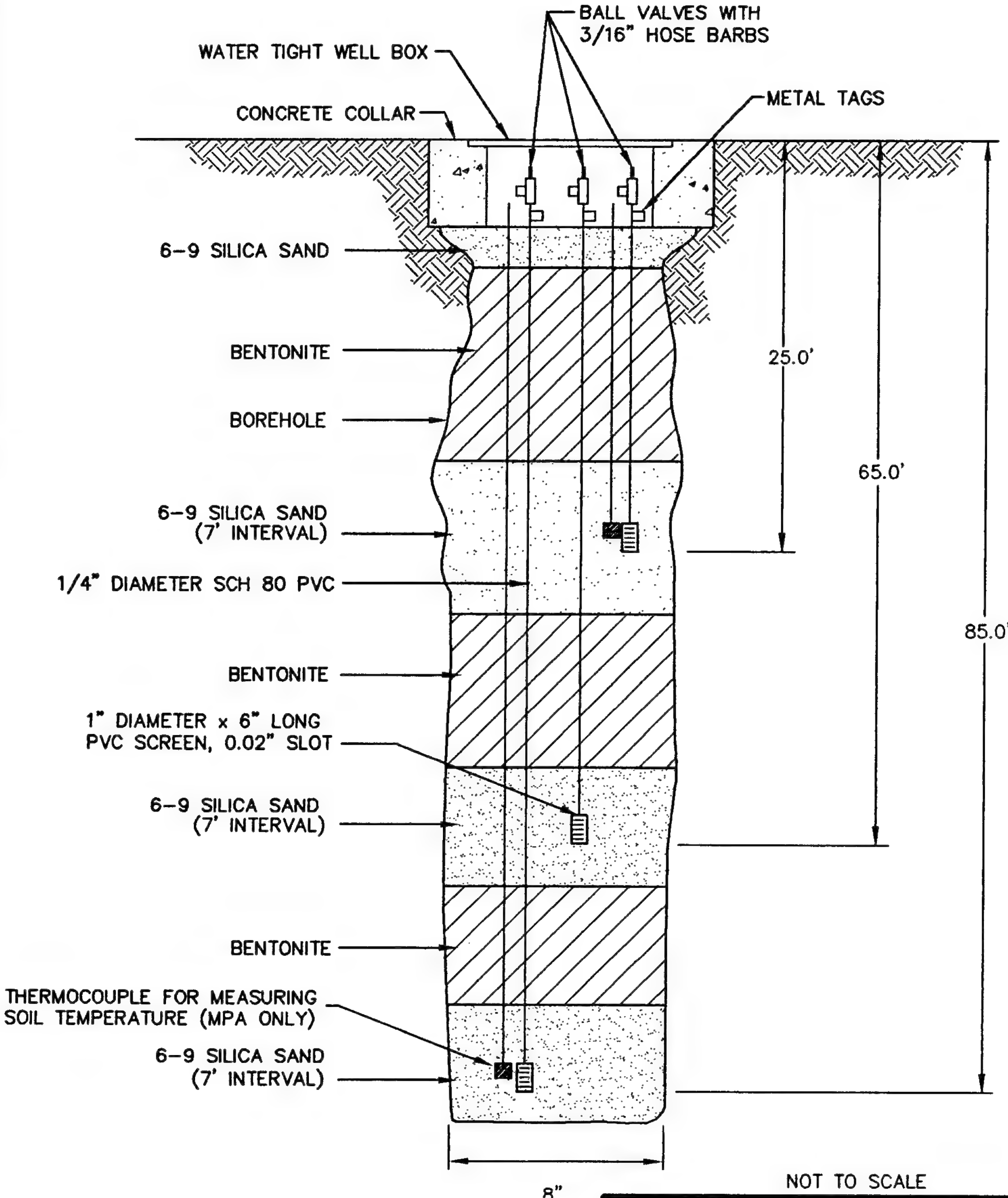

NOT TO SCALE

FIGURE 3.6

SITE ST12-B PROPOSED MONITORING POINT CONSTRUCTION DETAIL

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electrical equipment, buried electrical conduits, and necessary wiring will be provided by an electrical subcontractor hired by Parsons ES.

3.3.7 *In Situ* Respiration Tests

In situ respiration tests will be conducted in accordance with Subsection 2.3.7.

3.3.8 Air Permeability Test

The air permeability test at Site ST12-B will be conducted in accordance with Subsection 2.3.8.

3.3.9 Installation of 1-Year Pilot-Scale Bioventing System

The pilot-scale bioventing system to be installed at Site ST12-B will be in operation for a 1-year period. It is anticipated that the test blower will have a flow rate of approximately 125 scfm, distributing atmospheric air to both the VW and MW-7. The blower will be housed in a small, lockable, prefabricated sheds providing protection from the weather. Like Site ST10, the blower unit will be explosion-proof, and electrical wiring will be installed in accordance with NEC and Base codes for locations with potentially explosive atmospheres.

The system will be in operation for 1 year. System checks will be performed by Hickam AFB personnel once every two weeks. If required, major maintenance of the blower unit will be performed by Parsons ES personnel. Detailed blower system information and a maintenance schedule will be included in the O&M manual that will be provided to the Base. After the systems has operated for 1 year, Parsons ES personnel will return to the site to conduct *in situ* respiration testing and soil gas sampling to determine the long-term effectiveness of the system.

4.0 SITE ST12-A (WAIKAKALAUA FUEL STORAGE ANNEX)

This section discusses Site ST12-A, the results of successful bioventing pilot test activities at the site, and the expanded bioventing treatability study to be performed.

4.1 Site Description

Figure 3.1 (in the previous section) shows the location of Site ST12-A within the Waikakalaua FSA. Site ST12-A is located approximately 150 feet southeast of UST #8 and within 30 feet of the eastern boundary.

4.1.1 History of Site ST12-A

Similar to Site ST12-B, the open-bottomed drywell at Site ST12-A was previously used for disposal of waste petroleum products at the FSA. The initial subsurface investigation at the site occurred in 1988 with the drilling and installation of MW-6 (HLA, 1992). The installation of a pilot-scale bioventing system in April 1993 by Parsons ES (ES, 1993a) has provided further information regarding subsurface

contamination of the vadose zone and contaminant treatability at Site ST12-A. Figure 4.1 shows the layout of the pilot-scale bioventing system installed at Site ST12-A.

4.1.2 Geology and Hydrology at Site ST12-A

As previously discussed in Section 3.1.2, lithology at the Waikakalaua FSA, generally is composed of shallow deposits of unconsolidated clay and silt overlying a layer of saprolite. At Site ST12-A, the fill and colluvium extend to a depth of approximately 25 feet bgs, and the saprolite layer extends from 25 to 110 feet bgs. As is the case at Site ST12-B, basalt occurs at 110 feet bgs. During the installation of the bioventing pilot test system in April 1993, perched water was discovered approximately 55 feet bgs at MPA, MPB, MPC, and the VW. Additionally, a shallow zone of perched water was also encountered at MPA from 15 to 17 feet bgs. No perched water was discovered at the site in follow-up sampling performed in June 1994. Geologic boring logs of MW-6, the VW, and MPs, and construction details for MW-6 are included in Appendix B. The hydrogeology for Site ST12 was discussed previously in Section 3.1.2.

4.1.3 Contaminants at Site ST12-A

As is the case at Site ST12-B, the primary contaminants of concern at this site are petroleum hydrocarbons present in the vadose zone. Although leaks in the USTs and associated product piping are potential sources of contamination for Site ST12 in general, the drywell represents the only confirmed source of subsurface contamination for Site ST12-A. Elevated concentrations of petroleum hydrocarbon contaminants were detected in soil samples at depths below the drywell bottom (greater than 20 feet bgs). Table 4.1 provides initial soil hydrocarbon data for MW-6 and Soil Boring #2, as well as sample results following 1-year of pilot test bioventing at Site ST12-A.

At Site ST12-A, the highest contaminant concentrations detected during drilling associated with construction of monitoring well MW-6 included TRPH at 3,980 milligrams per kilogram (mg/kg). Contamination is known to extend to a depth of at least 88 feet bgs at this location (HLA, 1992). Further soil analytical data collected as part of the bioventing pilot test is presented in Section 4.2.

4.2 Previous Bioventing Test Results at Site ST12-A

This section describes the results of the previous bioventing pilot test performed by Parsons ES at ST12-A, and summarizes the results of a soil gas survey conducted by Parsons ES at the site on June 6, 1995.

4.2.1 Results of Bioventing Pilot Testing at Site ST12-A

A bioventing pilot test was performed at Site ST12-A by Parsons ES for AFCEE between March 1993 and June 1994. The pilot test was performed in initial and extended testing phases. Results of the initial pilot testing phase were reported by Parsons ES (ES, 1993a), and extended testing results were reported by AFCEE (1995). Results from the 1-year bioventing pilot test completed at Site ST12-A indicate the

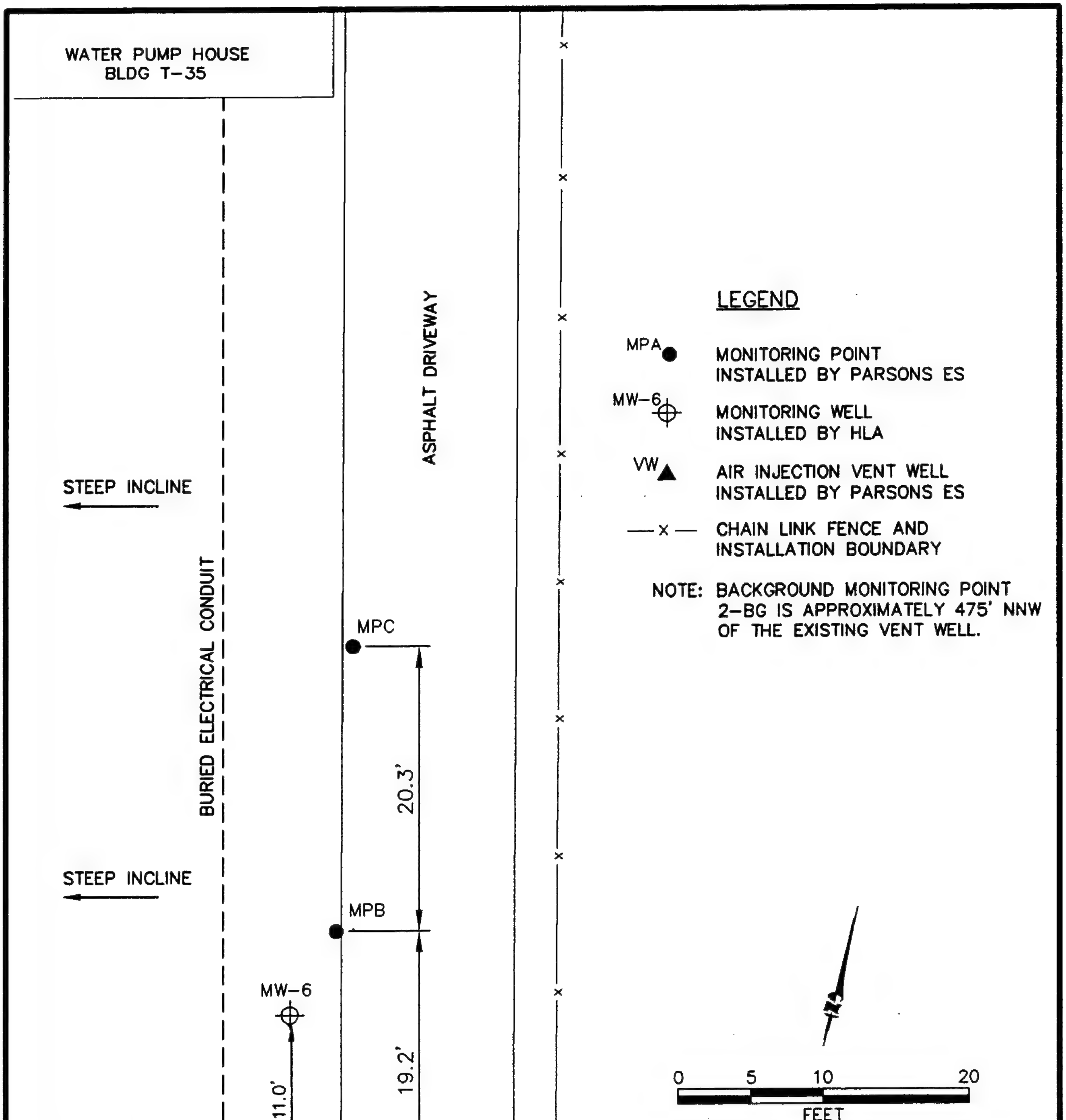

FIGURE 4.1

SITE ST12-A LAYOUT

Waikakalaua Fuel Storage Annex
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TABLE 4.1
CONTAMINANTS OF CONCERN AT SITE ST12-A
WAIKAKALAUA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

			Soil Hydrocarbons				
Sampling Location	Depth (ft bgs)[a/]	Reference	TRPH[b/] (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (mg/kg)
MW-6	32	HLA[c/]	3,980	NR[d/]	ND[e/]	57	92
MW-6	58	HLA	372	NR	1.3	ND	7.4
MW-6	88	HLA	674	NR	4.4	3.5	22
Boring 2	5	HLA	ND	NR	ND	ND	ND
Boring 2	16	HLA	373	NR	ND	ND	ND
Boring 2	25	HLA	1,530	NR	ND	7.1	28.3
VW	29.5	AFCEE[f/]	3,540	<3.9[g/]	<3.9	33	<5.5
VW	60	AFCEE	135	1.5	10.7	5.3	26.6
MPA	40	AFCEE	1,842	0.28	1.3	4.7	20
MPB	50	AFCEE	<7.5	0.0042	0.035	0.019	0.049

[a/] Sample depth in feet below ground surface.
[b/] TRPH = total recoverable petroleum hydrocarbons analyzed by EPA Method 418.1; mg/kg = milligrams per kilogram.
[c/] Harding Lawson and Associates, 1992.
[d/] NR = Not reported.
[e/] ND = Not detected.
[f/] AFCEE, 1995.
[g/] "<" denotes sample result was less than laboratory reporting limit.

effectiveness of *in situ* bioventing for enhancing biological fuel degradation in vadose zone soils.

The pilot test system at Site ST12-A was installed in March and April of 1993, and was designed to supply oxygen-rich soil gas to vadose zone soils contaminated from past disposal activities at the drywell (Figure 4.1). The air injection VW was placed less than 10 feet from the drywell to maximize aeration in areas thought to be most highly contaminated with petroleum hydrocarbons. MPA, MPB, and MPC were installed at distances of 9 feet, 19 feet, and 39 feet from the VW, respectively. Background MP 2-BG was installed to examine the characteristics of unimpacted soil and soil gas. During drilling and well installation, hydrocarbon-contaminated soils were encountered at depths below 20 feet bgs at MPA and the VW, and below 30 feet bgs at MPB. No significant petroleum contamination was discovered in soil at MPC, suggesting that the petroleum contamination may be contained within a 30 to 35-foot radius of the drywell.

4.2.1.1 Initial Soil Gas Conditions at Site ST12-A

An initial soil gas survey indicated that aerobic petroleum hydrocarbon biodegradation was occurring in vadose zone soils at rates fast enough to deplete the concentrations of oxygen in the soil gas, demonstrating the need for an active bioventing system to supply oxygen to the contaminated soils. Initial oxygen levels were depleted (0 to 5 percent) and carbon dioxide concentrations were elevated (3.8 to 11.3 percent) in soil gas from petroleum-contaminated soils. In contrast, soil gas from background MP 2-BG at 71 feet bgs contained oxygen at a concentration of 11.5 percent and carbon dioxide at a concentration of 0.3 percent, demonstrating that oxygen depletion and carbon dioxide accumulation in contaminated soil was due to the biodegradation of petroleum rather than the biodegradation of naturally occurring soil organic matter or abiotic processes. Soil gas samples could not be collected from a number of the MP screens due to high soil moisture concentrations and the presence of impermeable soils at some depth intervals (ES, 1993a).

4.2.1.2 *In Situ* Respiration Rates at Site ST12-A

In situ respiration testing was conducted to determine the rates at which native soil bacteria could biodegrade petroleum hydrocarbons. Table 4.2 summarizes the results of three *in situ* respiration testing events that occurred during the bioventing pilot test. Aerobic petroleum hydrocarbon biodegradation was estimated to occur at significant rates, ranging from 20 to 2,300 mg TRPH biodegraded per kg of soil per year and averaging 750 mg/kg per year. At a petroleum hydrocarbon biodegradation rate of 750 mg/kg per year, even the most highly contaminated soils, containing TRPH at concentrations up to 3,980 mg/kg, could theoretically be remediated to below 50 mg/kg within 5 years of bioventing system operation. Respiration and fuel biodegradation rates at the site have remained relatively constant over 1 year of extended testing (Table 4.2), indicating that the vadose zone soils still contain significant concentrations of readily biodegradable petroleum hydrocarbons and demonstrating the need for continued bioventing system operation.

TABLE 4.2
SITE ST12–A
RESPIRATION AND DEGRADATION RATES
WAIKAKALAUA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

Location–Depth (feet bgs)[a]	Initial = May 1993			6–Month[c] = Nov. 1993			1–Year = May 1994		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[b]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.0040	350	NS[d]	0.00036	20	NS	0.0025	110	NS
MPA–12.4	NS	NS	22.4	NS	NS	25.4	NS	NS	26.4
MPA–24.3	0.017	890	NS	0.013	1600	NS	0.011	2300	NS
MPA–70	NS	NS	26.2	NS	NS	25.1	NS	NS	25.6
MPB–36.1	0.0010	<10[e]	NS	NS	NS	NS	0.0018	100	NS
MPC–73.2	NS	NS	NS	0.00018	<10	NS	NS	NS	NS
MW–6	0.018	1130	NS	NS	NS	NS	0.020	1600	NS

[a] feet bgs = feet below ground surface.
[b] Milligrams of hydrocarbons per kilogram of soil per year.
[c] Assumes moisture content of the soil is an average between the initial and final readings.
[d] NS = not sampled.
[e] Although oxygen utilization was measured in these points, high levels of moisture are reducing the air–filled porosity of the soil and limiting oxygen supply to soil bacteria.

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4.2.1.3 Air Permeability at Site ST12-A

An air permeability test was performed at Site ST12-A to determine the volume of soil that could be oxygenated using a single VW. Air was injected into the VW for approximately 6 days, while pressure response and oxygen influence were measured at the MPs. There was no noticeable pressure or oxygen influence at any MP screens during the first 2 days of testing due to the impermeable nature of the soil at some depths, and due to the high moisture conditions brought on by the presence of perched water. Over the 6-day testing period, the air injection flow rate increased from 20 cfm to 75 cfm as soil moisture was displaced and preferential air flow channels developed in the soils. By the end of the 6-day test, significant pressure and oxygen influence were measured at MPA at 24.3 feet bgs, MPB at 36.1 feet bgs, and MPC at 37.6 feet bgs, demonstrating that a radius of influence of approximately 40 feet could be achieved in intermediate-depth soils (20 to 40 feet bgs) at the site.

Soil gas samples could not be collected from shallow (12.4 to 15 feet bgs) or deep (70 to 73.2 feet bgs) MP screens during the air permeability test because they were placed in impermeable and/or saturated soils. During the soil gas survey described in Subsection 4.2.2, it was demonstrated that the deeper intervals are now permeable enough to allow oxygen delivery, probably due to decreased soil moisture content at these depth intervals, and that the shallow intervals were still too impermeable to sample. The shallow MP screens were placed in uncontaminated soils above the zone of contamination, so oxygen delivery is not critical at these depth intervals. Generally, contaminated colluvium and saprolite at Site ST12-A are permeable enough to oxygenate using *in situ* bioventing.

4.2.1.4 Soil and Soil Gas Sampling Results at Site ST12-A

Soil and soil gas samples were collected during the installation of the pilot-scale bioventing system in March and April of 1993 to determine the initial contaminant concentrations at the site. Samples were collected from the same locations in May and June of 1994, after 1 year of pilot-scale system operation, to determine the degree of cleanup achieved after 1 year of pilot-scale soil treatment. Significant reductions in petroleum hydrocarbon concentrations occurred at Site ST12-A over 1 year of pilot-scale bioventing (Table 4.3).

Soil gas TVH and BTEX concentrations were reduced significantly at the VW and MPA. These reductions have been caused by enhanced biodegradation of fuel contaminants resulting from soil oxygenation, along with a minor amount of volatilization. Soil gas concentrations of TVH, ethylbenzene, and xylenes increased at MPC as a result of more highly contaminated soil gas being driven from the VW toward MPC during the testing period.

Soil petroleum hydrocarbon concentrations measured at the site during the 1-year study are not as conclusive as the soil gas results in demonstrating contaminant reductions. While TRPH concentrations decreased significantly in soil samples taken from the VW at 60 feet bgs and at MPB at 50 feet bgs; increases in TRPH

TABLE 4.3
SITE ST12-A
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
WAIKAKALAUA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

Analyte (Units) [a] — Sample Locations-Depth (feet below ground surface)

Soil Gas Hydrocarbons	VW		MPA-24.3		MPC-37.6		BG-70.6	
	Initial [b]	1-Year [c]	Initial	1-Year [d]	Initial	1-Year	Initial [d]	1-Year
TVH (ppmv)	19,000	1.9	22,000	16,000	250	3,200	77.5	4.6
Benzene (ppmv)	46	< 0.005	< 1.1	< 0.26	0.083	< 0.11	< 0.004	< 0.007
Toluene (ppmv)	86	< 0.005	< 1.1	< 0.26	0.450	< 0.11	0.030	< 0.007
Ethylbenzene (ppmv)	16	< 0.005	21	17	0.180	5.3	0.014	< 0.007
Xylenes (ppmv)	52	0.017	66	44	0.580	11	0.041	< 0.007

Soil Hydrocarbons	VW-29.5		VW-60		VW-90		MPA-40		MPB-50		BG-100	
	Initial [e]	1-Year [f]	Initial	1-Year [d]	Initial	1-Year	Initial	1-Year [d]	Initial	1-Year	Initial	1-Year
TRPH (mg/kg)	51.76	3,540	3,586	135	100	NS [g]	553.1	1,842	43.51	< 7.5	< 4.0	NS
Benzene (mg/kg)	< 0.52	< 3.9	1.7	1.5	1.6	NS	< 0.54	0.28	0.42	0.0042	< 0.6	NS
Toluene (mg/kg)	5.1	< 3.9	3.6	10.7	17	NS	4.5	1.3	29	0.035	< 0.7	NS
Ethylbenzene (mg/kg)	8.1	33	0.85	5.3	7.8	NS	6.5	4.7	14	0.019	< 0.5	NS
Xylenes (mg/kg)	40	< 5.5	4.1	26.6	44	NS	31	20	77	0.049	< 0.9	NS
Moisture (%)	32.6	36.6	33.4	32.5	29.3	NS	34.8	24.3	38.5	33.9	NS	NS

[a] TVH=total volatile hydrocarbons: ppmv = parts per million, volume per volume;
TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram.

[b] Initial soil gas samples collected on April 27, 1993.

[c] 1-Year soil gas samples collected on May 26, 1994.

[d] Results averaged with duplicate sample.

[e] Initial soil samples collected on March 29 to April 15, 1993.

[f] 1-Year soil samples collected on June 1 to 3, 1994.

[g] NS=Not sampled.

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concentrations were noted in the VW at a depth of 29.5 feet bgs and in MPA at a depth of 40 feet bgs. The increases in soil TRPH concentrations are most likely the result of local variations in contaminant concentrations, typical of discrete samples. To a lesser extent, similar inconsistencies are also evident with soil BTEX measurements. Generally, the BTEX concentrations show an overall decreasing trend over the one year study. This is significant since BTEX compounds represent the most toxic and mobile fuel contaminant hydrocarbons. BTEX compounds, while presenting the greatest risk, are more readily biodegradable than the remaining TRPH fraction. It is also important to note that soil gas measurements, as compared to discrete soil samples, are considered more representative of overall site conditions.

4.2.2 Results of Soil Gas Survey at Site ST12-A

A soil gas survey was conducted at Site ST12-A on June 6, 1995. The purpose of this survey was to determine the long-term radius of oxygen influence at the site. Results of this brief soil gas survey are summarized in Table 4.4.

High concentrations of oxygen in soil gas samples collected from depths of 24.3 to 73.2 feet bgs at MPA, MPB, and MPC (Table 4.4) indicate that the radius of oxygen influence for the current pilot-scale system is approximately 40 feet in permeable soil zones at these depth intervals. A soil gas sample collected from monitoring well MW-6 was anaerobic and contained elevated levels of carbon dioxide and TVH. These field sampling results indicate that the basalt at 135 to 150 feet bgs at MW-6 has been impacted by petroleum hydrocarbons, and that biological fuel degradation is likely occurring in the basalt. The expanded bioventing system described in the following section will be configured to allow the injection of air into MW-6 to deliver oxygen to local permeable zones of petroleum-impacted basalt.

4.3 Expanded Bioventing Treatability Study at Site ST12-A

The purpose of the expanded bioventing treatability study at Site ST12-A is to provide oxygen and stimulate aerobic biodegradation in an expanded volume of contaminated soil at the site. Because the extent of contamination is not yet known at the site, it is unknown if this effort will result in oxygenation of the entire volume of contaminated soil. One additional VW and manifolding to an existing MW will be installed for air injection, along with an additional MP, and an upgraded blower unit.

4.3.1 Layout of Expanded Treatability Test Components

The proposed upgrade to the existing bioventing system will include the addition of one VW, one MP, and an expanded blower system, as shown in Figures 4.2 and 4.3. Additionally, manifolding will be installed between the blower system and MW-6 to allow air injection at this point. The new VW (designated as VW-2) will be installed 30 to 40 feet south of the existing VW and drywell along the western side of the existing asphalt driveway. Placing the VW at this proposed location will allow the oxygenation of petroleum-impacted fill and saprolite south of the drywell. Also, the extent of contamination to the south of the drywell will be better characterized. The radii of influence around the two VWs should overlap sufficiently because the long-

TABLE 4.4
SOIL GAS CHEMISTRY AT SITE ST12-A
JUNE 6, 1995 SURVEY
HICKAM AFB, HAWAII

Monitoring Point	Screened Interval [a] (feet bgs)	Pressure (" H_20)	O_2 (percent)	CO_2 (percent)	TVH [b] (ppmv)
<u>**Site ST12- A**</u> [c]					
MPA	12.4	0.10	NA [d]	NA	NA
	24.3	0.25	19.2	0.6	700
	65-75	1.5	NA [e]	NA	NA
MPB	14.8	0.10	NA [f]	NA	NA
	36.1	0.28	NA [f]	NA	NA
	72.8	5.8	20.9	< 0.5	15
MPC	15	0.06	NA [f]	NA	NA
	37.6	7.0	NA [f]	NA	NA
	73.2	0.05	10.2	2.5	7,800
MW-6	135-150	0.34	0	11.5	1,500

[a] Designates screened interval and its depth below ground surface in feet. Center of interval measurements are given for monitoring points, except MPA 65-75.
[b] TVH=total volatile hydrocarbons; ppmv = parts per million, volume per volume.
[c] Soil gas measurements collected after 72 hours of bioventing system operation. Air injection flow rate approximately 75 cubic feet per minute.
[d] Sample could not be collected due to soil gas short circuiting to the atmosphere.
NA= Not analyzed.
[e] Sample could not be collected because the screened interval was flooded; perched water level was 63.15 feet bgs.
[f] Sample could not be collected due to highly impermeable soils.

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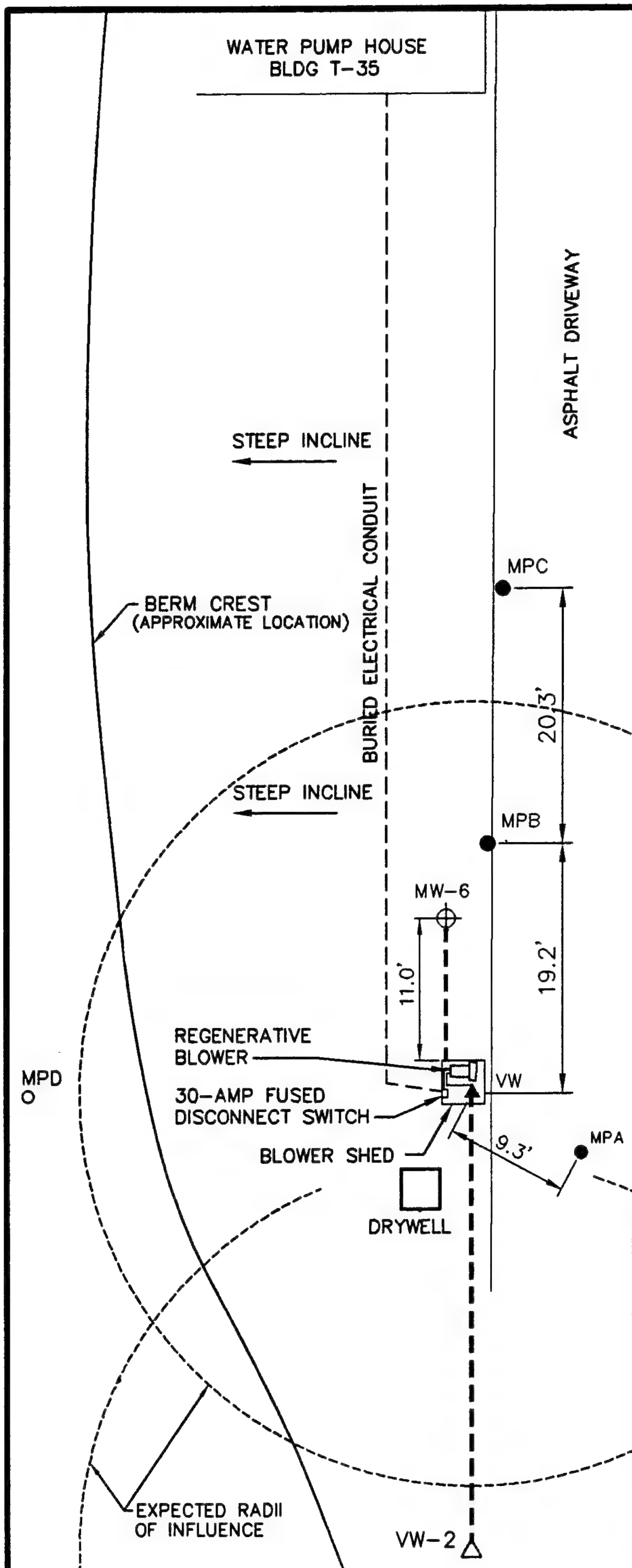

FIGURE 4.2

SITE ST12-A PROPOSED EXPANDED TREATABILITY TEST SITE LAYOUT

Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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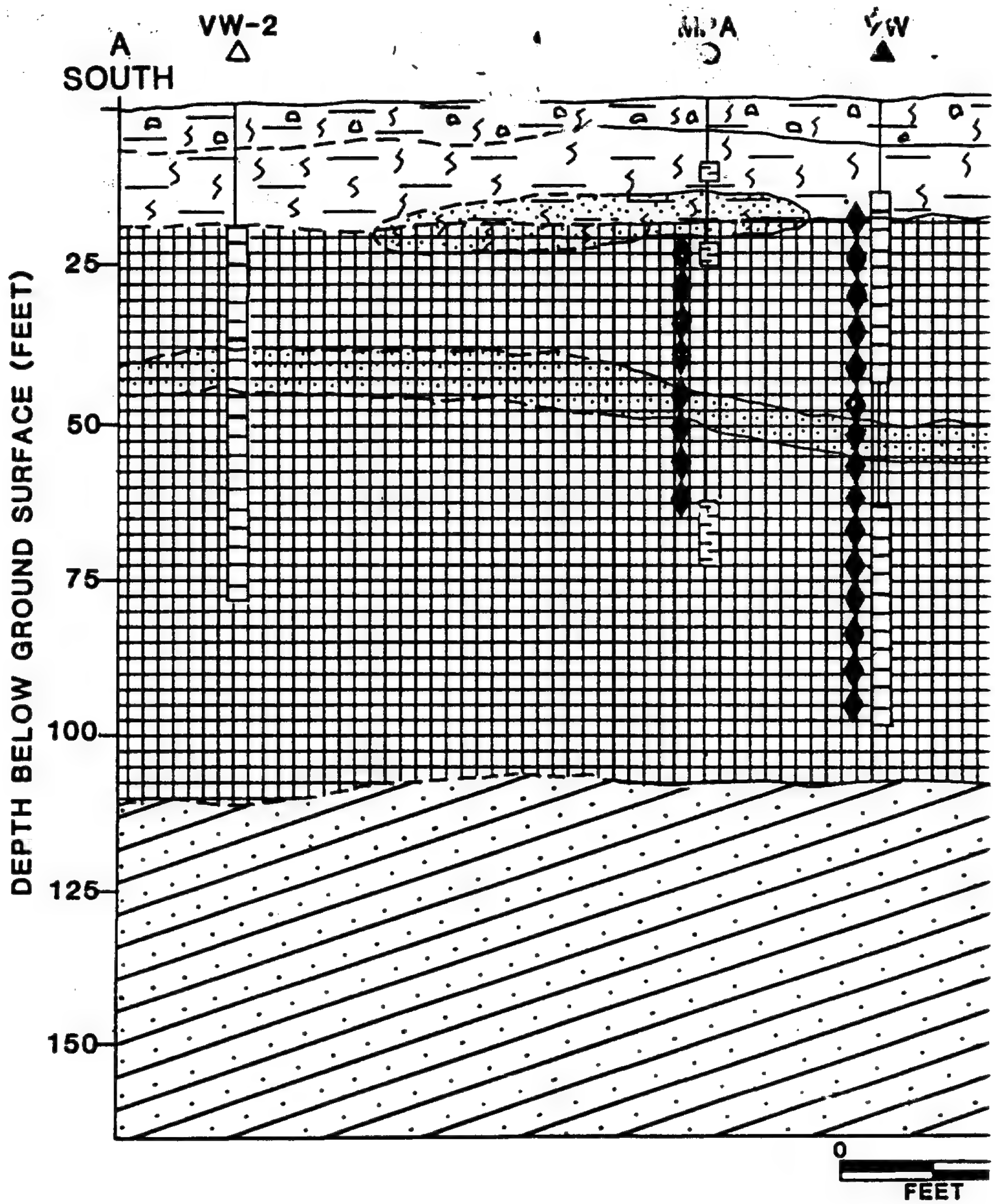


LITHOLOGIC DESCRIPTION

SILT WITH CLAY AND CORAL

SILT WITH CLAY

CLAY

SAPROLITE

ZONES PERCH

LEGEND

MPA EXISTING MONITORING POINT

VW EXISTING INJECTION VENT WELL

VW-2 PROPOSED VENT WELL

MW-6 EXISTING MONITORING WELL

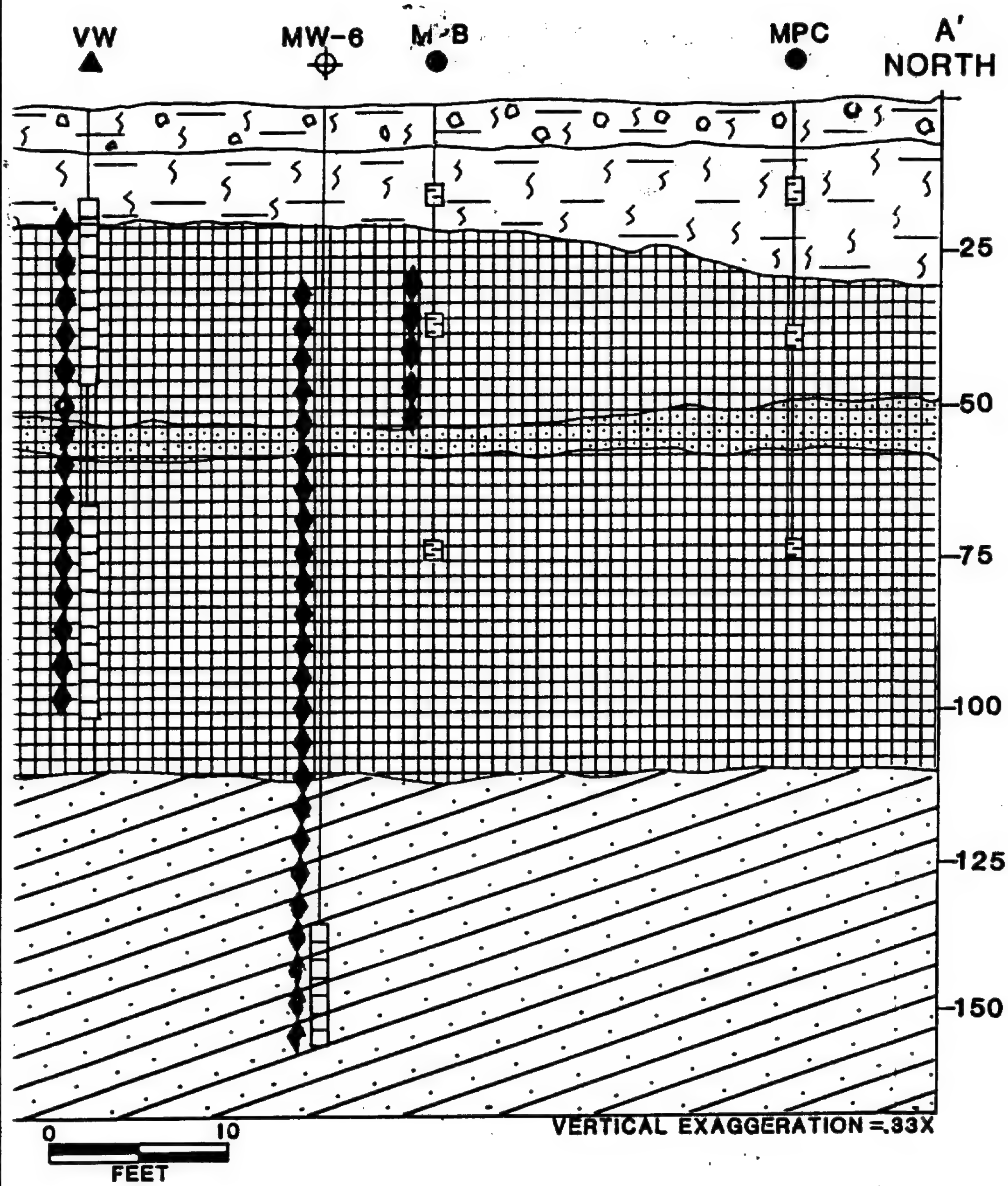
FIELD EVIDENCE OF CONTAMINATION

GEOLOGIC CONTACT WHERE INFERRED

MONI SCRE

SCRE

42 /



ZONES OF PERCHED WATER

BASALT

MONITORING POINT SCREENED INTERVAL

SCREENED WELL INTERVAL

FIGURE 4.3

SITE ST12-A
GEOLOGIC CROSS-SECTION

Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

PARSONS ENGINEERING SCIENCE, I
Denver, Colorado

term radius of oxygen influence during the pilot test was measured at 40 feet from the VW. Air injection into MW-6 will provide oxygen-rich soil gas to petroleum-impacted and oxygen-depleted basaltic layers between 135 and 150 feet bgs. The additional MP (designated as MPD) will be installed approximately 35 feet west of the existing VW.

This proposed location will allow information to be collected regarding the western extent of contamination at Site ST12-A. The existing blower system and shed will be removed and replaced with a new, larger blower system and shed set on a concrete pad.

4.3.2 Vent Well Installation

Figure 4.4 illustrates the proposed construction for the new VW at the site. The VW will be constructed of 4-inch diameter, Schedule 40 PVC pipe, with an approximate 80-foot interval of 0.04-inch slotted screen set at approximately 20 to 100 feet bgs. A two-screen configuration may be required to prevent perched water, if present, from entering the well casing. Flush-threaded, PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6-9 grain size and will be placed in the annular space of the screened interval from the bottom of the borehole to at least 2 feet above the top of the screen. A 13-foot layer of bentonite will be placed directly over the filter pack. The bentonite seal will be placed in 1-foot layers, with each lift of bentonite hydrated with potable water prior to the addition of subsequent layers. A competent bentonite seal is critical to prevent injected air from short-circuiting to the surface during air injection. The VW surface completion will consist of a 12-inch diameter, flush-mounted wellhead protector emplaced in a concrete pad.

4.3.3 Monitoring Point Installation

A new MP (MPD) will be constructed as shown in Figure 4.5. Soil gas oxygen, carbon dioxide, and TVH concentrations will be monitored at approximate depth intervals of 30, 55, and 90 feet bgs (the middle screen will be placed at the elevation of the perched water zone encountered during drilling in April 1993 (ES, 1993a); depths of shallow and deep screens may vary due to the potential presence of perched water onsite). Multi-depth monitoring at the new MPs will determine whether the soil profile affected by the expanded system is receiving oxygen.

The MP will be constructed with 3 vapor probes placed in 6-9 silica sand. Each vapor probe, constructed of 6-inch-long sections of 1-inch diameter PVC well screen, will be centered in a 7-foot layer of 6-9 silica sand. The annular spaces between monitoring intervals will be sealed with bentonite to isolate the intervals. The bentonite will be placed in 1-foot layers and hydrated with potable water prior to placement of subsequent layers to ensure complete saturation of the bentonite.

4.3.4 Soil and Soil Gas Sampling

Soil and soil gas samples will be collected before the system is started to establish baseline conditions in expanded areas, and to further define the magnitude and extent of contamination at Site ST12-A.

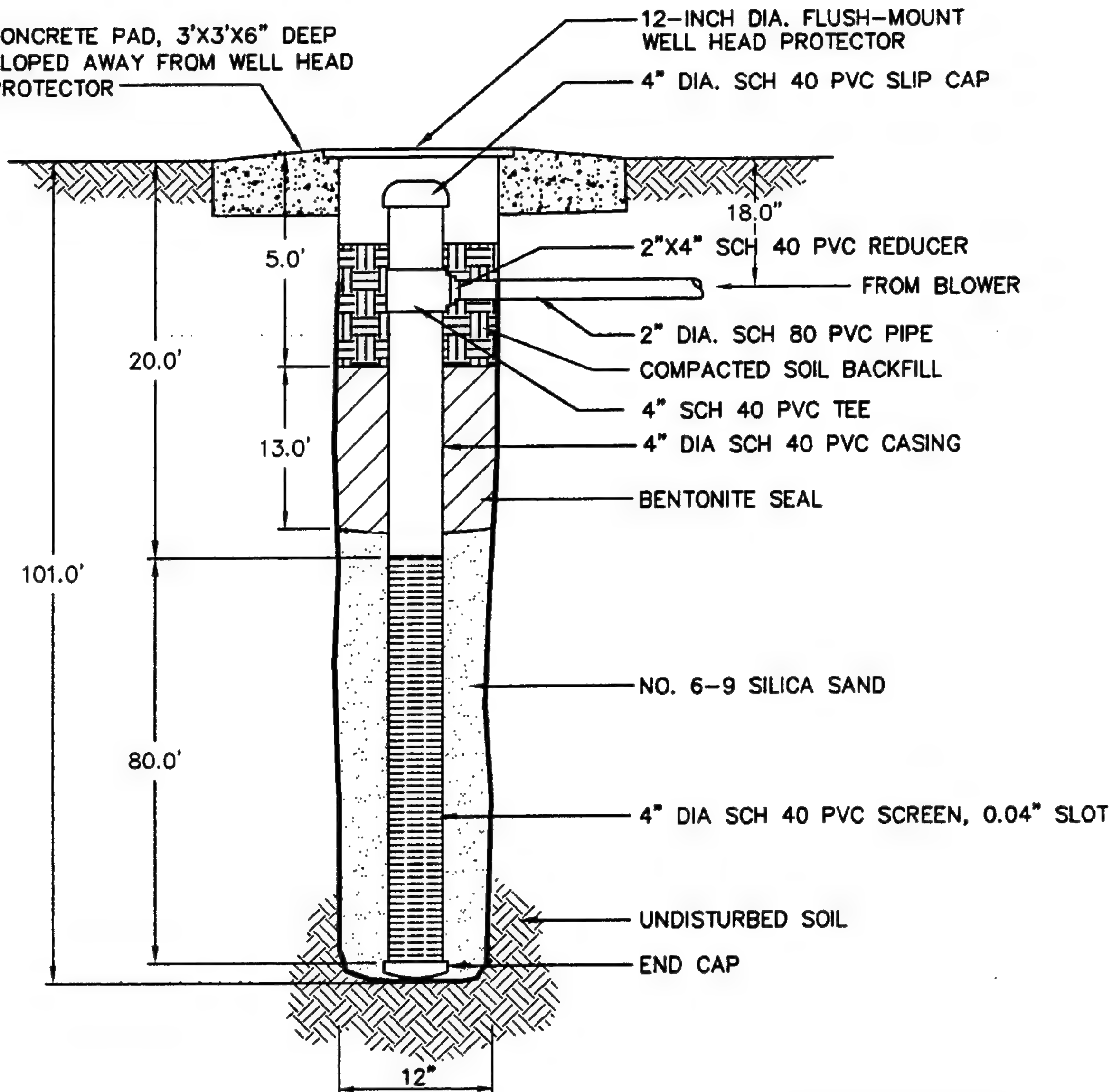


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FIGURE 4.4

SITE ST12-A PROPOSED INJECTION VENT WELL CONSTRUCTION DETAIL

Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

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Denver, Colorado

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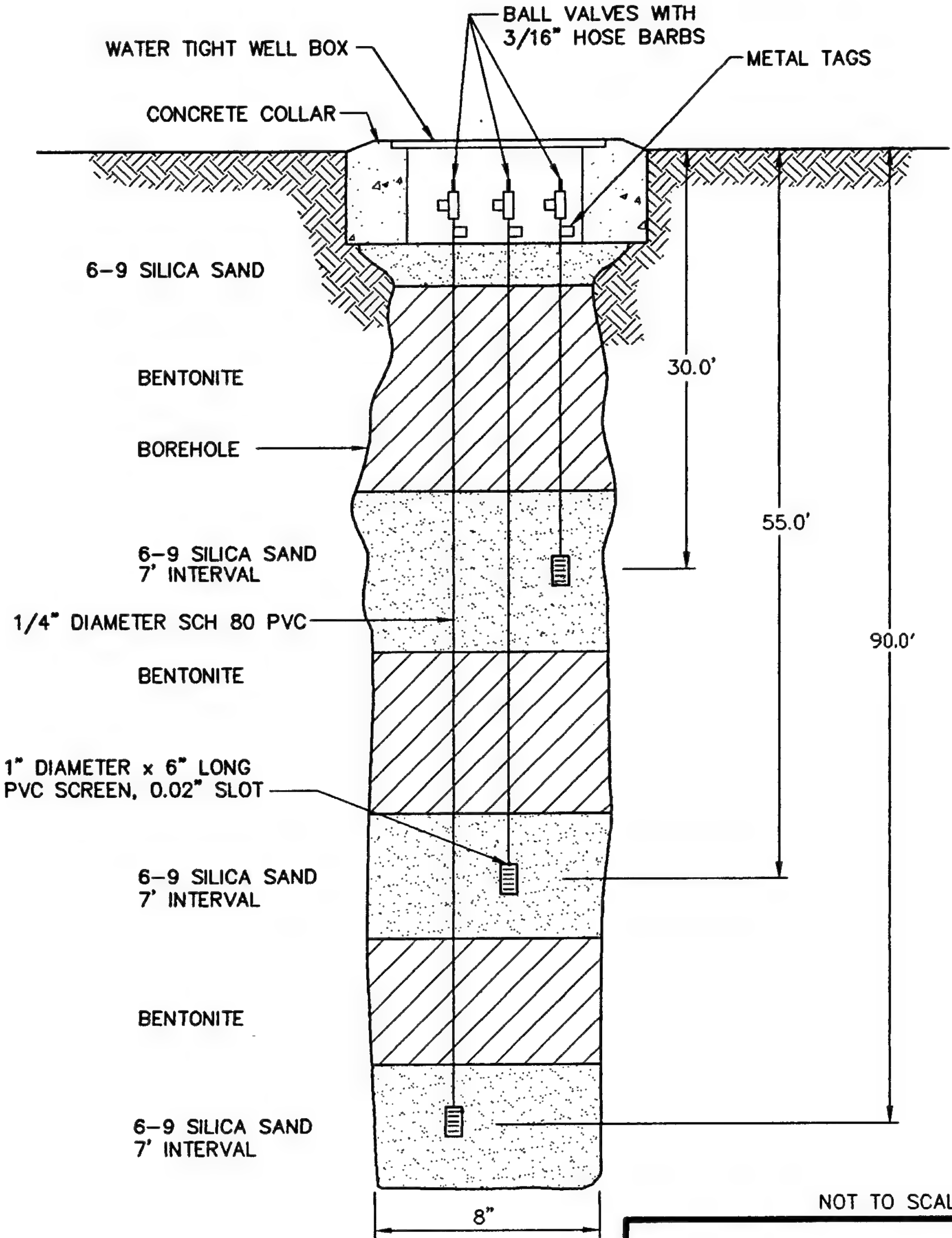

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FIGURE 4.5

SITE ST12-A
PROPOSED MONITORING POINT
CONSTRUCTION DETAIL

Waikakalaua Fuel Storage Annex
Hickam AFB, Hawaii

PARSONS
ENGINEERING SCIENCE, INC.
Denver, Colorado

4.3.4.1 Soil Sampling

Between five and seven soil samples will be collected for laboratory analysis during installation of VW-2 and MPD. Sampling procedures will follow those outlined in the protocol document (Hinchee *et al.*, 1992). A TVH vapor analyzer will be used during drilling to screen split-spoon samples for intervals of high fuel contamination. Split-spoon samples will be collected at 10-foot intervals at Site ST12-A. Based on field screening results, samples from the most highly contaminated locations will be analyzed for TRPH by EPA Method 8015 (modified) and BTEX by EPA Method 8020. If extensive contamination is encountered during drilling, up to 7 samples may be collected for TPH and BTEX analysis. Sample collection and handling will be conducted in accordance with procedures outlined in Subsection 2.3.5.1.

4.3.4.2 Soil Gas Sampling

Soil gas samples will be collected from the VWs, MW-6, and the MPs and field-screened for oxygen, carbon dioxide, and TVH. Soil gas samples from the five most contaminated locations will be collected in SUMMA® canisters in accordance with the Bioventing Field Sampling Plan (ES, 1992) and submitted for laboratory analysis of BTEX and TPH by EPA Method TO-3. These soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and TVH after 1 year of system operation, and to detect any migration of these vapors from the source areas. Sample collection and handling will be conducted in accordance with procedures outlined in Subsection 2.3.5.2

4.3.5 Blower System Installation

A 5.5-horsepower regenerative blower system capable of injecting air at a flow rate of 200 cfm will be installed in a new blower enclosure at the location of the current pilot-scale blower system. This blower system has been conservatively sized so that 2 to 4 additional VWs, installed with screened intervals in either the saprolite or deeper basalt layer, can easily be added to the system in the future, to achieve oxygenation of the entire fuel-contaminated area. Both VWs and MW-6 will be manifolded to the blower system. Separate throttling valves will allow flow to be balanced between the 3 wells. The blower at Site ST12-A will be powered by 480-volt, three-phase, 20-amp power obtained from inside Building T-35. If possible, existing subsurface conduit installed during the initial pilot test will be used to route the conductors. Installation of electrical equipment, buried electrical conduits, and necessary wiring will be provided by an electrical subcontractor hired by Parsons ES.

Based on data collected during the initial pilot test, an air injection rate of 50 cfm at each VW should be sufficient to attain a long-term radius of oxygen influence of 40 feet from each VW, sustaining aerobic *in situ* fuel biodegradation within this radius.

4.3.6 Blower System Startup and Operation

4.3.6.1 System Startup

During the startup of the expanded system, the air injection rate into each VW will be optimized. Flow rate optimization is accomplished by gradually increasing the air flow to each VW until all MPs reach a minimum oxygen concentration of approximately 10 percent. The blower will be checked to ensure that it is producing the required flow rate and pressure for air injection.

4.3.6.2 System Operation and Monitoring

Following startup, the system will be in operation for 1 year. Monitoring of the bioventing system will include system checks once every two weeks of the blower operation, including outlet pressures, inlet vacuum, and exhaust temperature. System checks will be the responsibility of Hickam AFB. Any major blower system repairs that are required during the first year of system operation will be the responsibility of Parsons ES.

4.3.6.3 Extended Testing

Parsons ES technicians will return to the site following one year of operation to perform the following scope of work. A comprehensive system check will be conducted to determine the long-term radius of oxygen influence at the site. An *in situ* respiration test will be performed to ensure biodegradation of fuel residuals is continuing at acceptable levels. Finally, soil gas samples will be collected from the same locations as the initial sampling event and analyzed for BTEX and TVH using EPA Method TO-3 to determine the degree of cleanup achieved over the year-long period.

5.0 HANDLING OF INVESTIGATION-DERIVED WASTES (IDW)

Disposition of drill cuttings will be based on physical appearance (i.e. odor and staining) and field soil headspace screening results. Uncontaminated soil will be spread on the ground surface adjacent to each boring, and contaminated drill cuttings will be placed in a temporary lined landfarm at Site ST12, in accordance with procedures outlined in the Investigation-Derived Wastes Management Plan for Hickam Petroleum, Oil, and Lubricant Storage Annexes and Pipeline (ES, 1993b). One composite sample of the landfarmed soil will be collected and analyzed during the 1-year sampling event. In addition to BTEX and TRPH analysis, the landfarmed soil will be analyzed for polycyclic aromatic hydrocarbons (by EPA Method 8270), ethylene dibromide (by EPA Method 8260), and lead (by EPA Method 7421). Final disposition of the landfarmed soil will be based on the results of this sampling event.

6.0 BASE SUPPORT REQUIREMENTS

The following Base support is needed prior to the arrival of the drilling subcontractor and the Parsons ES pilot test team:

- Assistance in obtaining drilling and digging permits;
- An access agreement which will allow the installation of VW-1 and VW-2 at their proposed locations on private property at Site ST10;
- Gate passes and security badges for the Parsons ES bioventing team and the drilling subcontractor.
- Vehicle passes for one Parsons ES truck, and a drill rig and supply truck.

During initial testing and system installation, the following Base support is needed:

- Approval of selected decontamination areas at ST10 and ST12 where the driller can clean augers between borings;
- Approval of the selected area for the temporary lined landfarm;
- A potable water supply for well construction and decontamination activities.

During the 1-year extended pilot test, Base personnel will be required to perform the following activities:

- Check the blower systems once every two weeks to ensure that they are operating, and to record the air injection pressure and other parameters. Parsons ES personnel will provide a brief training session on this procedure.
- If a blower stops working, notify Mr. Greg Pierson or Mr. John Bridenbaugh of Parsons ES-Honolulu at (808) 944-8009, Mr. John Ratz of Parsons ES-Denver at (303) 831-8100, or Lt. Maryann Jenner of AFCEE at (210) 536-4364.
- Arrange site access for a Parsons ES technician to conduct respiration testing and soil gas sampling approximately 1 year after the initial pilot testing and system installation.

7.0 PROJECT SCHEDULE

The following schedule is contingent upon approval of this pilot test work plan and completion of base support requirements.

Event	Date
Draft Work Plan to AFCEE/Hickam AFB	*27 July 1995*
AFCEE/Hickam AFB/Regulator comments to Parsons ES	*14 August 1995*
Final Work Plan to AFCEE/Hickam AFB	22 *September 1995*
Regulatory Approval	*September 1995*

Initial Pilot Testing/System Expansion	*October 1995*
Letter Results Report/As-Builts/O&M Manual	*December 1995*
Final Respiration Test and Soil Gas Sampling	*November 1996*
Letter Results Report	*December 1996*

8.0 POINTS OF CONTACT

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ph: (808) 944-8009
FAX: (808) 944-1618

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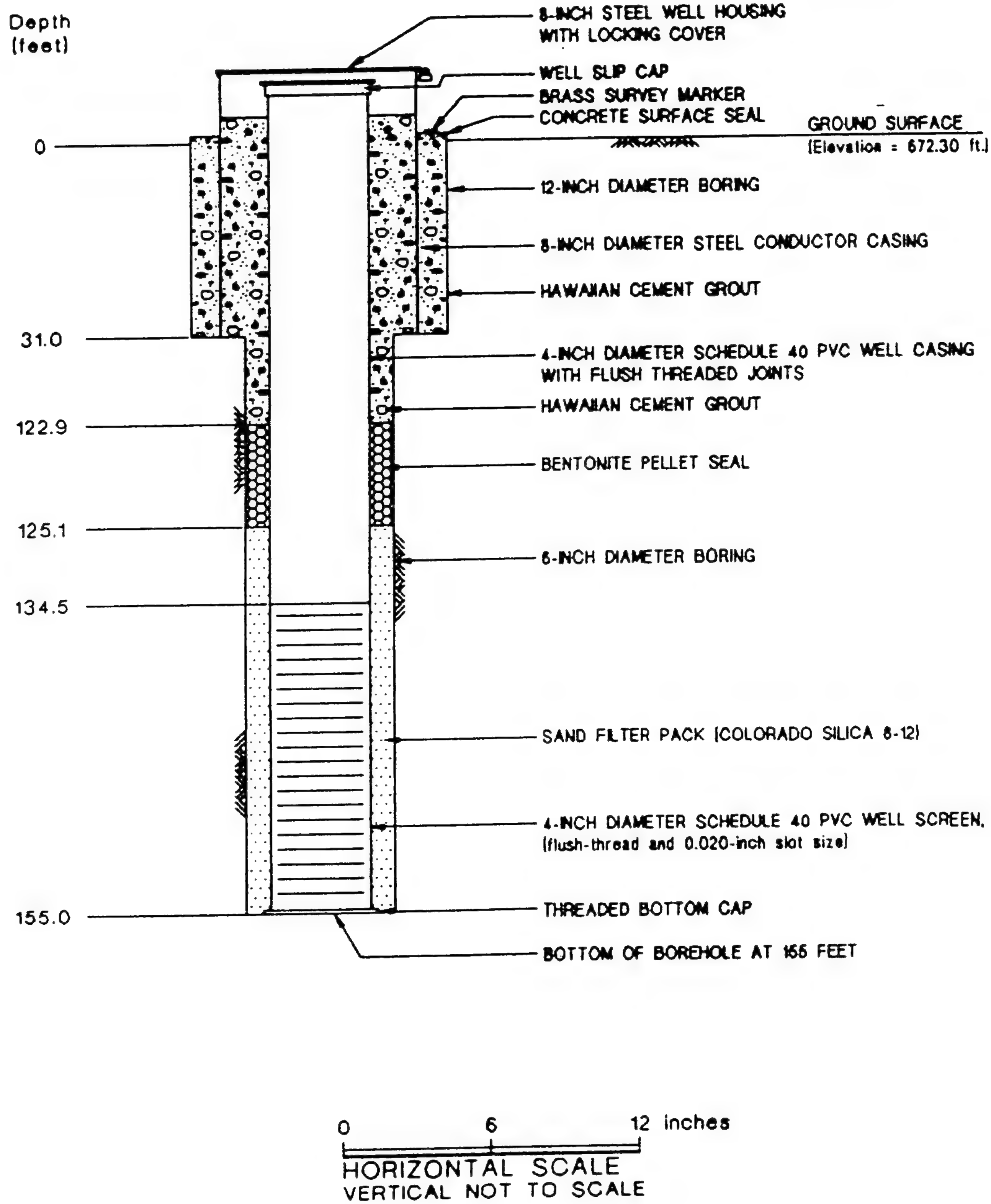
APPENDIX A

GEOLOGIC BORING LOGS AND WELL CONSTRUCTION DETAILS FOR SITE ST12-B



HLA Harding Lawson Associates
Engineers and Geoscientists

Monitoring Well MW-7, Waikakalaua
Hickam POL Fuel Storage
IRP Stage 2 Technical Report - Site 2
Island of Oahu, Hawaii

PLATE **E-75**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
gwl	04300,031.06		07/89		

Equipment Mobile B80L - Air Rotary

Elevation 672.30 ft Date 2/11/88

Blows/ foot	OVA Reading (ppm)	Sample Depth (ft)	Description
		0	PINKISH GRAY GRAVELLY SAND - (5YR, 7/2), dry, loose, (fill) DARK REDDISH BROWN SILT (ML) - (5YR, 3/3), moist, stiff
		10	
			at 17.5 feet, color change to DARK RED, (2.5YR, 3/6)
		20	at 20.0 feet, color change to STRONG BROWN, (7.5YR, 4/6)
		30	at 30.0 feet, color change to DARK REDDISH BROWN, (5YR, 3/3)
24	38.0		at 31.5 feet, color change to VERY DARK GRAY, (5YR, 3/1) at 33.8 feet, color change to WEAK RED, (2.5YR, 5/4), (saprolite)
		40	at 42.0 feet, color change to DARK REDDISH BROWN, (5YR, 3/4) at 45.0 feet, color change to DARK REDDISH GRAY, (5YR, 4/2) at 47.5 feet, color change to STRONG BROWN, (7.5YR, 5/8)
		50	at 52.5 feet, color change to YELLOWISH BROWN, (10YR, 5/4) at 55.0 feet, color change to BROWNISH YELLOW, (10YR, 6/6)
>50	140.0		at 57.5 feet, color change to OLIVE-GRAY, (5Y, 5/2), silt becomes hard, with some iron-oxide staining, (saprolite)
		60	
			at 65.0 feet, color change to DARK REDDISH BROWN, (5Y, 3/2)
		70	at 72.5 feet, color change to BROWN, (10YR, 5/3)
			at 76.0 feet, color change to OLIVE-GRAY, (5Y, 4/2)
		80	

Harding Lawson Associates
Engineers and Geoscientists

Log of Boring MW-7
Waikakalaua Fuel Storage Annex - Site 2
IRP Stage 2 Technical Report
Island of Oahu, Hawaii

PLATE **E-61**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
kar	04300,031.06				

Blows/ foot	OVA Reading (ppm)	Sample Depth (ft)	(Continuation of Log)
		80	OLIVE-GRAY SILT (ML) - (5Y, 4/2), hard (saprolite) at 83.0 feet, color change to DARK REDDISH GRAY, (10R, 3/1) at 88.0 feet, color change to VERY DARK GRAY, (2.5Y, N3/0),
38	>1000		
		90	
		100	
			OLIVE-GRAY BASALT - hard, moderately strong, little weathering
		110	
			at 114.0 feet, color change to MODERATE BROWN
		120	
			at 124.0 feet, color change to OLIVE-GRAY
		130	
			at 137.5 feet, color change to PALE YELLOWISH BROWN
		140	
		150	
			Bottom of boring at 155.0 feet.*

* NOTE: Boring drilled an extra five feet due to borehole instability (sidewall caving).

Harding Lawson Associates
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Log of Boring MW-7 (Continued)
Waikakalaua Fuel Storage Annex - Site 2
IRP Stage 2 Technical Report
Island of Oahu, Hawaii

PLATE **E-62**

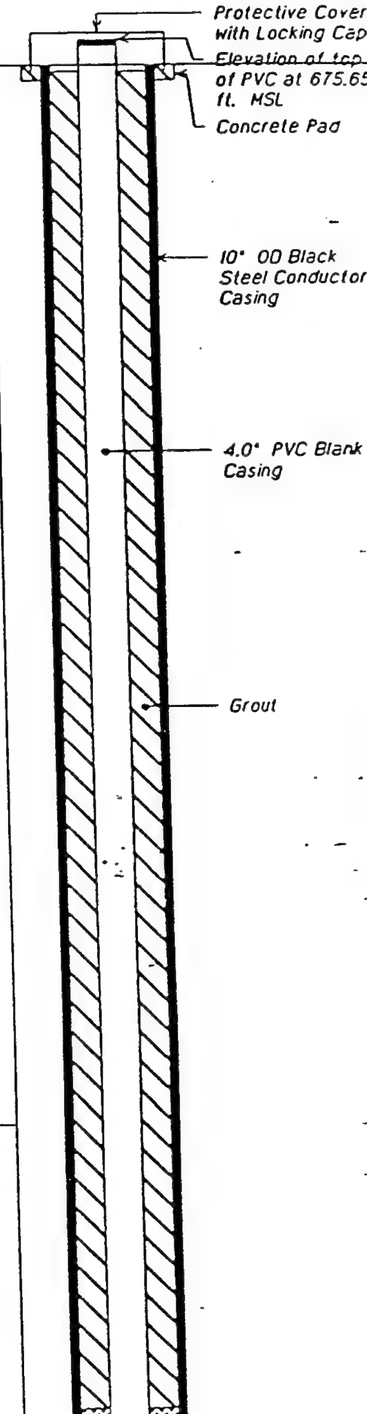
DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
kar	04300,031.06				

ES	ENGINEERING-SCIENCE, INC. 1357 Kapiolani Blvd., Suite 1120 Honolulu, Hawaii 96814	Log of Monitoring Well ST12MW03

PROJECT: Hickam POL	LOCATION: Waikakalaua Fuel Storage Annex
PROJECT NO.: 723200	SURFACE ELEVATION: 673.62 ft. MSL
DATE STARTED: 01-MAR-93	INITIAL H2O LEVEL: 21.68 ft. MSL
DATE FINISHED: 17-MAR-93	FINAL H2O LEVEL: 22.22 ft. MSL
DRILLING METHOD: Air Rotary	TOTAL DEPTH: 670 Feet
DRILLING COMPANY: SSSI	LOGGED BY: N. Matsumoto

DEPTH feet	SAMPLE	PID (ppm)	LITH. CODE	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
0			STCL		CL	CLAY AND SILT: dark reddish brown to dark brown, low to high plasticity, dry to moist, with patches of weathered minerals observed.
5		9				
10						
15						
20		5				
25						
30						
35						
40		0				
45						
50						
55						
60		47				
65						
70						
75						
80		236				
82			STCL		CL	SAPROLITE: dark grayish brown, low plasticity, damp to moist, with chunks of slightly weathered basalt.
85		332				
90						
95						
100		535				
105						

WELL DIAGRAM



ES ENGINEERING-SCIENCE, INC.

1357 Kapiolani Blvd., Suite 1120
Honolulu, Hawaii 96814

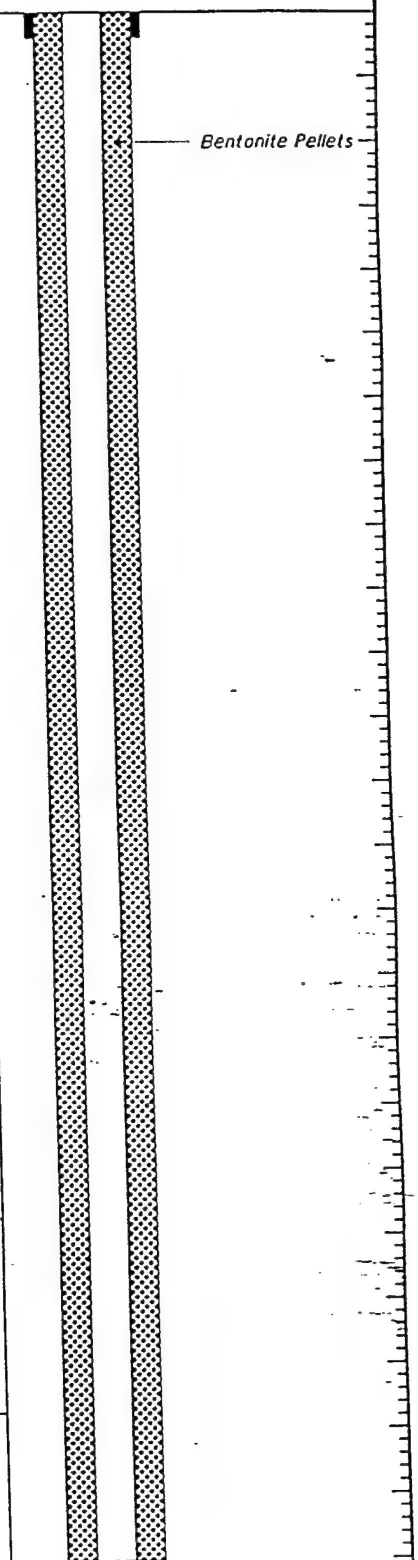
Log of Monitoring Well ST12MW03

PROJECT: *Hickam POL*

LOCATION: *Waikakalaua Fuel Storage Annex*

DEPTH feet	SAMPLE	PID (ppm)	LITH. CODE	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
			STCL		CL	
110, 115, 120		104, 232	VLBA		NACM	**WEATHERED BASALT:** dark gray, gravel to cobble sized, angular to well rounded fragments. Some clay, dark gray with some very dark gray patches. No odor, no flouresence.
125, 130, 135, 140, 145		35, 0	VLBA		NACM	**WEATHERED BASALT:** light olive gray, porphyritic, vesicular, weathered olivine, pyroxene and amphibole crystals. RQD 10% to 54%. Grades to **CLAY:** Brownish gray, medium plasticity with angular to subangular basalt gravel.
150, 155			VLBA		NACM	**WEATHERED BASALT:** light olive gray, porphyritic, vesicular, no fractures, weathered olivine crystals. RQD 48.5%.
160, 165			VLBA		NACM	**BASALT:** medium gray with greenish-gray flecks, aphanitic, slightly vesicular, horizontal and vertical fractures, RQD 60.3%. No staining, no odor.
170			VLBA		NACM	**BASALT:** olive gray, porphyritic, slightly vesicular, weathered olivine, pyroxene and amphibole crystals. RQD 50%.
175			VLBA		NACM	**BASALT:** moderate brown, porphyritic, vesicular, horizontal fractures. RQD 57.8%. No staining, no odor.
180, 185			VLBA		NACM	**BASALT:** medium greenish gray, aphantic, horizontal fractures.
190, 195		1	VLBA		NACM	**BASALT:** light brown, porphyritic, vesicular, vertical and horizo horizontal fractures, olivine, pyroxene crystals. RQD 63%. No staining, no odor, no flouresence.
200, 205, 210		1	VLBA		NACM	**BASALT:** dark yellowish brown, porphyritic, vesicular, vertical fractures, olivine, pyroxene crystals. RQD 89%. No staining, no odor, no flouresence.
215, 220, 225			VLBA		NACM	**BASALT:** dusky red, aphanitic, vesicular, mostly rubble, some weathered olivine, pyroxene and calcite crystals. RQD 15%. Black staining, no odor, no flouresence.

WELL DIAGRAM



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Log of Monitoring Well ST12MW03

PROJECT: *Hickam POL*

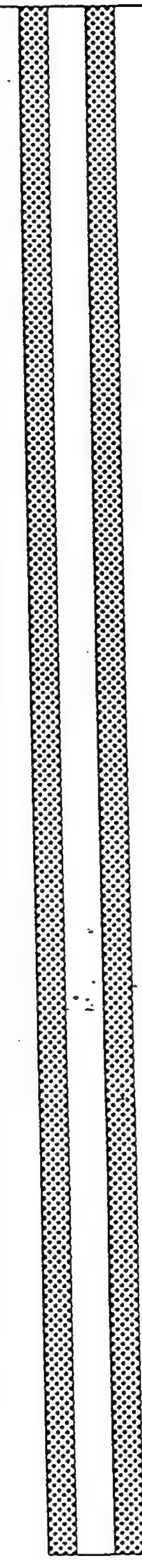
LOCATION: *Waikakalaua Fuel Storage Annex*

Depth (feet) scale: 230, 235, 240, 245, 250, 255, 260, 265, 270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335, 340, 345

PID (ppm): 1 (at approx. 310 ft)

LITH. CODE	SOIL CLASS	GEOLOGIC DESCRIPTION
VLBA	NACM	**BASALT:** dusky red, aphanitic, vesicular, mostly rubble, some weathered olivine, pyroxene and calcite crystals. RQD 15%. Black staining, no odor, no flouresence.
VLBA	NACM	**BASALT:** dark yellowish brown, porphyritic, vesicular, horizontal fractures, olivine and pyroxene crystals. RQD 100%. No staining, no odor, no flouresence.
VLBA	NACM	**BASALT:** dusky red to grayish brown, aphanitic to porphyritic, vesicular, vertical and horizontal fractures, few olivine, pyroxene, and calcite crystals.
VLBA	NACM	**BASALT:** dusky red to grayish brown, aphanitic to porphyritic, with olivine, pyroxene and secondary calcite crystals. Horizontal and vertical fractures. RQD from 50% to 53%. Some black staining, no odor, no flouresence.
VLBA	NACM	**BASALT:** dusky red, aphanitic, vesicular, mostly rubble clinker. RQD 21%.
VLBA	NACM	**BASALT:** grayish brown, aphanitic, vesicular, with horizontal and vertical fractures. Some reddish brown weathering along fractures and some black staining. RQD 54% to 70%. Grades to clinker, RQD 28%.

WELL DIAGRAM



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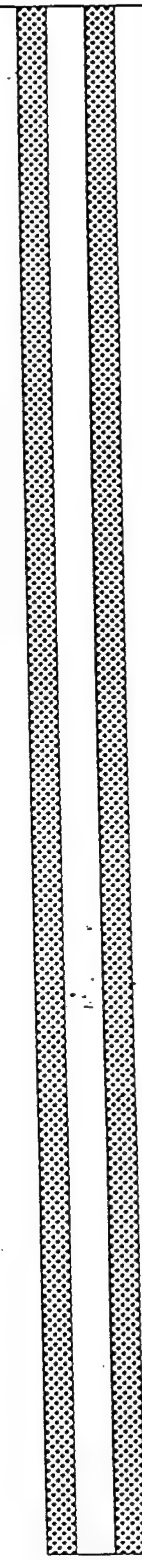
Log of Monitoring Well ST12MW03

PROJECT: *Hickam POL*

LOCATION: *Waikakalaua Fuel Storage Annex*

DEPTH feet	SAMPLE	PID (ppm)	LITH. CODE	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
350		0	VLBA		NACM	**BASALT:** grayish brown, aphanitic, vesicular, with horizontal and vertical fractures. Some reddish brown weathering along fractures and some black staining. RQD 54% to 70%. Grades to clinker, RQD 28%.
355						
360						
365						
370		1	VLBA		NACM	**BASALT:** pale brown to dark reddish brown, aphanitic to phaneritic, few olivine crystals, horizontal to vertical fractures. Some black staining, no odor, no flouresence. RQD 39% to 81%.
375						
380						
385						
390		0	VLBA		NACM	**BASALT:** grades from dark reddish brown to grayish brown, aphanitic, vesicular, vertical and horizontal fractures, olivine crystals and some very tiny crystals too small to identify with hand lens. RQD 81%.
395						
400			VLBA		NACM	**BASALT:** dark gray, porphyritic to aphanitic, some olivine and pyroxene crystals, vesicular, horizontal and vertical fractures. Some clinker. RQD 16% to 74%.
405						
410		0				
415						
420						
425						
430		0				
435						
440			VLBA		NACM	**BASALT:** medium gray, porphyritic, olivine crystals, vesicular, vertical and horizontal fractures. Some black staining, no odor, no flouresence. RQD 0% to 78%.
445						
450		1				
455						
460						
465						

WELL DIAGRAM



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Honolulu, Hawaii 96814

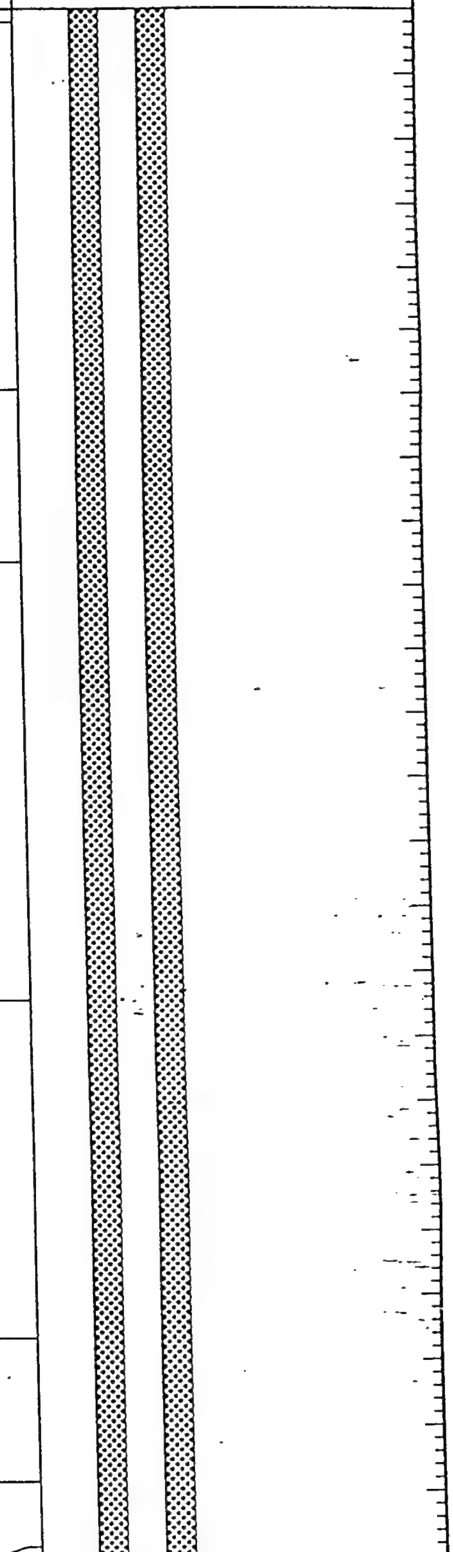
Log of Monitoring Well ST12MW03

PROJECT: *Hickam POL*

LOCATION: *Waikakalaua Fuel Storage Annex*

DEPTH feet	SAMPLE	PID (ppm)	LITH. CODE	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
470, 475, 480, 485, 490		0, 0	VLBA		NACM	**BASALT:** medium gray, porphyritic, olivine crystals, vesicular, vertical and horizontal fractures. Some black staining, no odor, no flouresence. RQD 0% to 78%.
495, 500, 505			VLBA		NACM	**BASALT:** dusky red to medium gray, aphanitic to porphyritic, olivine crystals, vesicular, vertical and horizontal fractures. Some black staining in fractures. RQD 89%.
510, 515, 520, 525, 530, 535, 540		0, 0	VLBA		NACM	**BASALT:** dusky red to medium gray, aphanitic, weathered olivine, pyroxene, calcite and amphibole crystals, vesicular, vertical and horizontal fractures. Some black staining, no odor, no flouresence. RQD 94% to 50%.
545, 550, 555, 560, 565		0	VLBA		NACM	**BASALT:** dusky red to medium gray, aphanitic to porphyritic, olivine and pyroxene crystals, vesicular, vertical and horizontal fractures with weathering along fractures. Some black staining, no odor, no flouresence. RQD 95% to 54%.
570, 575		0	VLBA		NACM	**BASALT:** medium gray to dark gray, porphyritic, plagioclase feldspar crystals, vesicular, vertical and horizontal fractures. Some pahoehoe structure. RQD 99% to 77%.
580			VLBA		NACM	**BASALT:** dark reddish brown to dusky red, aphanitic, vesicular, mostly rubble. Some black staining. Some pahoehoe structure.
585			VLBA		NACM	**BASALT:** pale red, porphyritic, vesicular, mostly rubble. Olivine crystals. RQD 50%.

WELL DIAGRAM



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Log of Monitoring Well ST12MW03

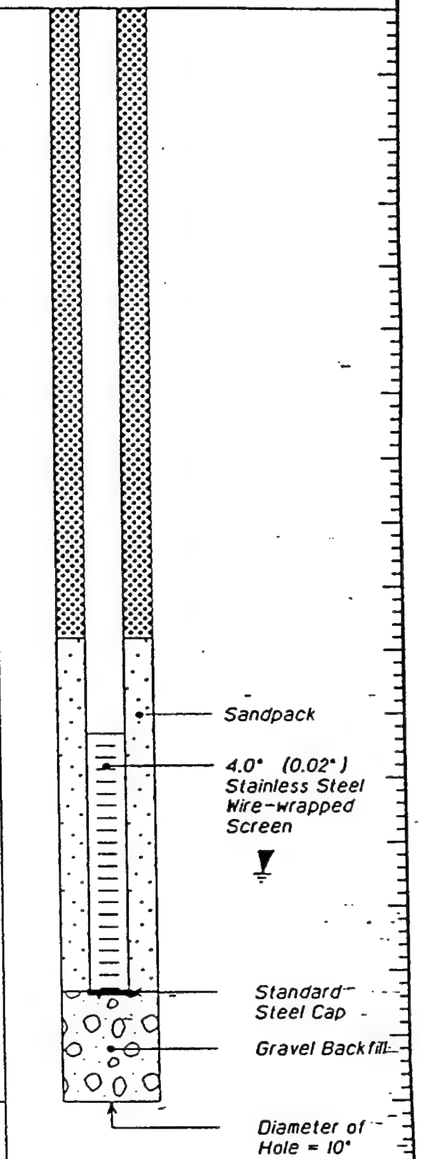
PROJECT: *Hickam POL*

LOCATION: *Waikakalaua Fuel Storage Annex*

DEPTH feet	SAMPLE	PID (ppm)	LITH. CODE	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION
			VLBA		NACM	**BASALT:** grayish red, aphanitic, vesicular, mostly rubble-"clinker". Some interbedded saprolite.
			VLBA		NACM	
590		0	VLBA		NACM	**BASALT:** medium gray, porphyritic, vesicular, olivine crystals, vertical and horizontal fractures, some weathering along fractures RQD 49%.
610		1	VLBA		NACM	**BASALT:** moderate reddish brown, aphanitic, vesicular, clinker.
615			STCL		CL	**SAPROLITE:** grayish red.
			VLBA		NACM	**BASALT:** medium gray to pale reddish brown, porphyritic, olivine crystals, vesicular, vertical and horizontal fractures, much rubble. Some black staining. RQD 58% to 88%.
630		0				
640			VLBA		NACM	**BASALT:** moderate reddish brown to grayish red, aphanitic, vesicular, vertical and horizontal fractures, mostly rubble. RQD 33% to 99%.
645			VLBA		NACM	**BASALT:** pale red to dark gray, porphyritic, olivine crystals, vertical and horizontal fractures. Some black staining, no fluoresence. Strong TPH odor at 651 FBGS. RQD 59% to 44%.
650		0				*Groundwater at 651.94 FBGS*
662						*TD of Well at 661.83 FBGS*
670						*TD of Hole at 670 FBGS*

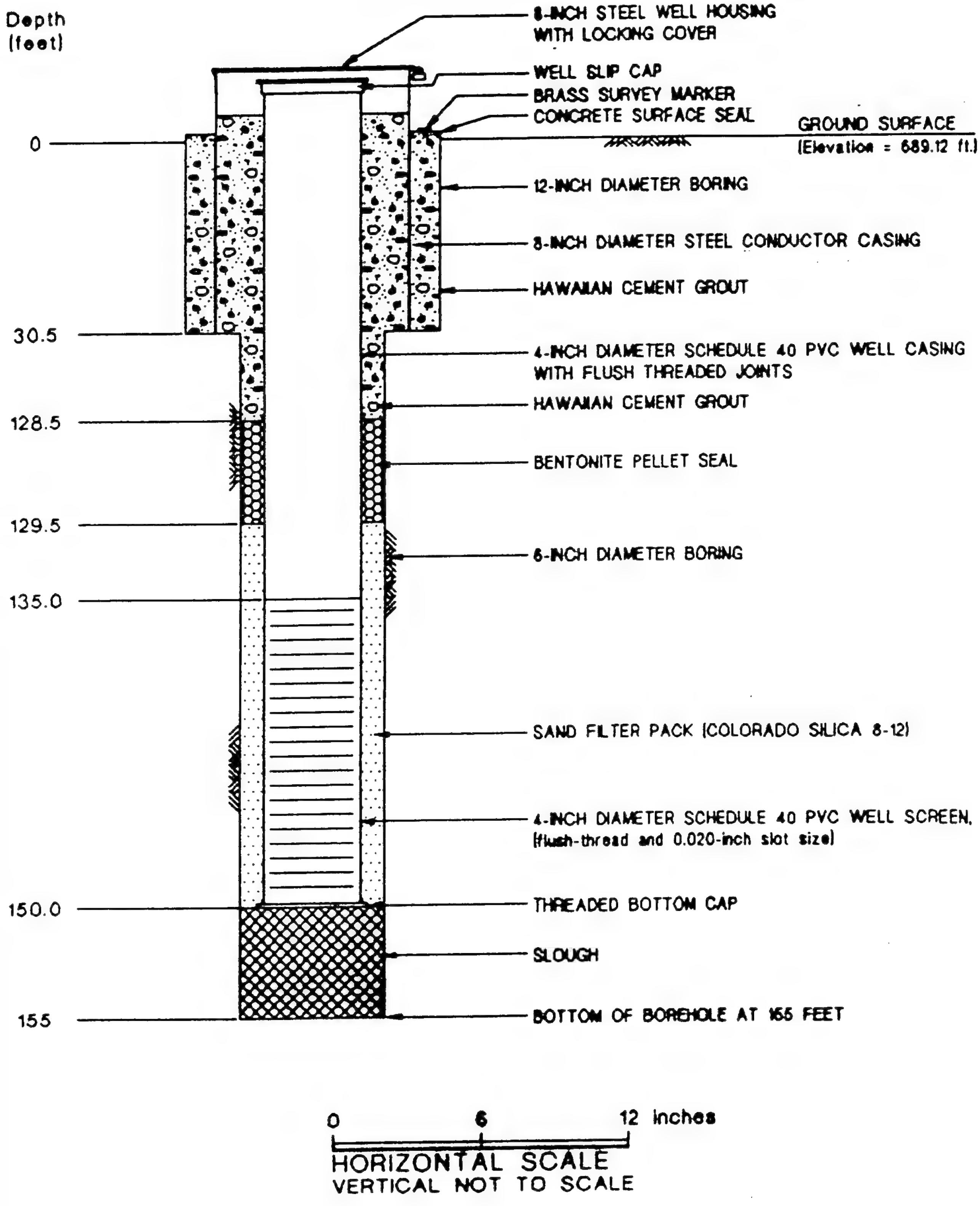
Depth scale: 590, 595, 600, 605, 610, 615, 620, 625, 630, 635, 640, 645, 650, 655, 660, 665, 670, 675, 680, 685, 690, 695, 700, 705

WELL DIAGRAM



APPENDIX B

GEOLOGIC BORING LOGS AND WELL CONSTRUCTION DETAILS FOR SITE ST12-A



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Monitoring Well MW-6, Waikakalaua
Hickam POL Fuel Storage
IRP Stage 2 Technical Report - Site 2
Island of Oahu, Hawaii

PLATE **E-74**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
gwl	04300,031.06		07/89		

Equipment Mobile B80L - Air Rotary

Elevation 689.12 ft Date 2/9/88

Blows/ foot	OVA Reading (ppm)	Sample Depth (ft)	Description
		0	DARK REDDISH BROWN CLAYEY SILT (ML) - (2.5YR, 3/4), moist, (fill)
		10	
			at 15.0 feet, color change to REDDISH BROWN, (5YR, 4/3)
		20	GRAY, (7.5YR, 5/0), and DARK REDDISH GRAY, (5YR, 4/2), SAPROLITE
			at 27.5 feet, color change to VERY DARK GRAY, (5YR, 3/1)
46	>1000	30	at 32.5 feet, saprolite becomes hard at 34.0 feet, color change to VERY DARK GRAYISH BROWN, (10YR, 3/2)
		40	
		50	
>50	>1000	60	
		70	at 72.0 feet, color change to DARK REDDISH BROWN, (5YR, 3/4)
		80	

HLA

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Log of Boring MW-6
Waikakalaua Fuel Storage Annex - Site 2
IRP Stage 2 Technical Report
Island of Oahu, Hawaii

PLATE
E-59

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
kar	04300,031.06				

Blows/ foot	OVA Reading (ppm)	Sample Depth (ft)	(Continuation of Log)
		80	
35	>1000		at 88.0 feet, occasional fine sand pockets
		90	
			at 93.0 feet, color change to DARK GRAYISH BROWN, (10YR, 4/2)
		100	
		110	DARK GRAY BASALT - hard, moderately strong
		120	
		130	
		140	at 140.0 feet, color change to PALE RED
		150	
			Bottom of boring at 155.0 feet.*

* NOTE: Boring drilled an extra five feet
due to borehole instability (sidewall caving).

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Log of Boring MW-6 (Continued)
Waikakalaua Fuel Storage Annex - Site 2
IRP Stage 2 Technical Report
Island of Oahu, Hawaii

PLATE **E-60**

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
kar	04300,031.06				

PROJECT: LOCATION ID.: Site 2 Vent Well	LOG OF BORING:
DATE STARTED: 3-30-93	GEOLOGIST/ENGINEER: Craig A. Miller / John Ratz
DATE COMPLETED: 4-1-93	NOTES:
DRILLING METHOD: HSA	BOREHOLE DIAMETER: 10.5"
SAMPLING METHOD: Split Spoon	SURFACE CONDITIONS: 85°F, Sunny grass & Asphalt
DRILLER: GeoLABS	

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	USCS	L.C.	NOTES
1						1'; Silt with clay and Coral Fragments 1.5"-3", Some organics, Dark Brown Loosly Consolidated. No odor or Staining. DRY				Fast Drilling ↓
2										
3										
4										
5						4'; Silt with clay and Coral Fragments 1/4-1/2". SAA				
6										
7										* Soil becoming moist @ 5' Bgs
8										* End of Coral @ 7' Bgs
9		X	?	12"						
10						9'; Silt with clay, Dark Rusty Red well consolidated. Very moist. No staining or odor. Some wood Fragments				0.0 ppm Ambient 19.6 ppm baggie HDSP
11										
12										- Cuttings coming up very Blocky - Sticky texture
13										
14										
15										
16										
17										
18						19'; Saprolite - Light orange Brown with multicolored minerals. olivine and Secondary Calcite. Vesicular 1-2mm. moderately consolidated moist. No odor or staining.				0.0 ppm ambient 69.5 ppm baggie HDSP
19										
20					SAPROLITE ↓					* @ 21' Ammonia odor detected
21										
22										
23										
24										@ 25' Drilling Rate Slowing Down
25										
26										
27										
28										
29		X	12 13 15 18	24"		29'; Saprolite - med Brown with Some orange weathered patches. Blocky Slightly vesicular. Very moist. odor and some black staining present				0.0 ppm Ambient 1286 ppm baggie HDSP
30										

PROJECT:
LOCATION ID: Site 2 - Vent Well

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
31					↑					
2					S					
3					A					
4					P					
5					R					
6					o					
7					L					
8					I					
39		X	7	12"	T	39'; Saprolite - Dark Brown and Black. very homogenous. moderately Consolidated. slight, vesicular (1-2mm). very moist. odor and Black staining present				0.0 ppm Ambient 4,726 baggie NDSP
40					E					
1					↓					
2										
3										- cuttings coming up slow
4										
5										
6										
7										
8										
9		X		12"		49'; Saprolite - SAA				* 49' very strong odor
50										
1										* Found water @ 52' bgs
2					▽					
3										
4										
5										- cuttings not coming out of hole. must be saturated & sticking to auger
6										
7										
8										
59		X	18 19 31 32	24"		59'; Saprolite - Dark Brown. approx. 10% Sand. moderately consolidated. non vesicular. very moist. odor but no staining				0.0 ppm ambient 1,800 ppm baggie NDSP
60										

NOTES:

PROJECT:
LOCATION ID.: Site 2-Vent well

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C.	NOTES
1										-Cuttings Slowly Coming out of hole
2										
3										
4										- Slow Drilling
5										
6		X	?	12"		69'; Saprolite - olive Green with Red patches. very Consolidated. Low moisture. Slight odor and No Staining.				0.0 ppm Ambient 1200 ppm baggie HDSP
7										
8										
9										
70										Slow Drilling
1										
2										
3										
4										
5										
6										
7										@ 77' Cuttings became very wet and Clay in Texture.
8										
9		X	?	12"		79'; Saprolite. olive Brown. Hard and well consolidated. Slightly vesicular. moist. mod. odor, No STAINING.				0.1 ppm Ambient 1,286 ppm baggie HDSP
80										
1										
2										
3										
4										Slow Drilling
5										
6										
7										
8										
9		X	?	12"		89'; Saprolite - medium Brown. Hard, very Vesicular (2-7mm) Fractures easily, moist slight odor. mineral staining				0.0 ppm Ambient 685 ppm baggie HDSP
90										

NOTES:

PROJECT:
LOCATION ID: SITE 2 - Vent well | LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN/ GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C.	NOTES
91										Slow Drilling
2										
3										
4										
5										
6										
7										-Cutting still coming up wet.
8										
9										
100										
1										
2		X	?	24"		102'; Saprolite - Light grayish Brown moderately hard and consolidated. vesicular (1-3mm). moist, slight odor and mineral staining				0.0 ppm ambient 757 ppm baggie HNSF
3										
4										-Drilled an extra 2 feet for RAT hole
5										
6						TDBGS @ 102'				
7										
8										
9										
1										
2										
3										
4										
5										
6										
7										
8										
9										

NOTES:

PROJECT: LOCATION ID.: NI-Z-MPA	LOG OF BORING:
DATE STARTED: 4-15-93	GEOLOGIST/ENGINEER: C. Miller, J. Ratz
DATE COMPLETED: 4-16-93	NOTES:
DRILLING METHOD: HSA	BOREHOLE DIAMETER: 10¼"
SAMPLING METHOD: Split Spoon	SURFACE CONDITIONS: asphalt and grass
DRILLER: Beclares	

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C.	NOTES
1						0-2" Black asphalt grading into Reddish Brown Silt and organics. Coral fragments ¾" - 1½".				Fast Drilling
2										
3										
4										
5										* End of coral @ 5'
6										
7										
8										- @ 8' Auger Began to move horizontally
9										
10		X	11	6"		10'; Silt with clay, Dark Rusty Red. well consolidated, very homogeneous texture. very moist. no staining or odor.				0 ppm ambient
11										14 ppm HOSp Baggie
12										
13										
14										
15										- @ 15' cuttings become very blocky.
16										
17										- @ 15-17' Drilling became very easy
18										
19										
20		X	8	6"	SAPROLITE	20'; Saprolite, very Dark Rusty Brown, with some weathered patches, blocky, non-vesicular. very moist, no staining but strong Hydrocarbon odor.				- 0 ppm ambient
21										- 260 ppm baggie HDSP
22										- @ 20' noticed evidence of water could be only a lens or saturated soil.
23										
24										
25										
26										- 22' Drilling slowed Down Do to wet cuttings
27										
28										- @ 28' easy Drilling again
29										
30		X				See next page for 30' sample				- Auger walked about 1.5' Horizontally since 8' BGS

Engineering-Science, Inc. PROJECT NO.

PROJECT:
LOCATION ID: N1-2-MPA

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
31		X	75	6"	SAPROLITE	31'; Saprolite. Dark Brown with weathered orange patches, well consolidated, very vesicular, Black staining with very strong odor, moist.				0 ppm Ambient 2300 ppm baggie HDSP Moderate Drilling Speed
2–9										-cutting still coming up in sludge texture
40		X	11 14 17 19	24"		40'; Saprolite - Dark Brown to Black very homogeneous, moderately consolidated vesicular (1-4mm). Complete Black staining with very strong odor. moist				0 ppm Ambient 1800 ppm baggie HDSP - Drilling slow because of wet cuttings
1–9										
50		X	5 7 10 13	24"		50'; Saprolite. orangish Brown with red weathered patches. moderately consolidated slightly vesicular, no staining but some odor of solvent, moist				0.0 ppm ambient 440 ppm Baggie HDSP
1–9										Slow Drilling
60										

NOTES: HDSP: Head Space

PROJECT:
LOCATION ID: H1-2-MPA

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
1										Drilling still slow. wet cuttings are difficult to identify
2										
3										
4						S				
65		☒	20	6"	A	65'; Saprolite, Light Brown with				-0ppm Ambient
6					P	Red unidentified mineral assemblage				-880 ppm Baggie Nosp
7					R	Poorly Consolidated, Slightly				-@72' Drilling
8					O	vesicular, Black staining with				became Difficult
9					L	odor, moist				and slow
70					I					
1					T					
2					E					
3										
4										
75		☒	20	6"		75'; SAA TD BGS 75'				-0.0ppm Ambient
6										-780 ppm Baggie Nosp
7										
8										
9										
1										
2										
3										
4										
5										
6										
7										
8										
9										

NOTES:

PROJECT: LOCATION ID.: HZ-2-MPB	LOG OF BORING:
DATE STARTED: 4-9-93	GEOLOGIST/ENGINEER: C Miller, J. Rotz
DATE COMPLETED: 4-13-93	NOTES:
DRILLING METHOD: HSA	BOREHOLE DIAMETER: 10 3/4" 0-60, 8" 6-75
SAMPLING METHOD: Split Spoon	SURFACE CONDITIONS: grass and asphalt
DRILLER: GeoLabs	

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	USCS	L.C.	NOTES
1						0'; Silt with clay and coral fragments 1.5"-3". Some organics, Loosly Consolidated. No odor or staining (0-1' bgs) Dark Brown in color, Dry				Fast Drilling
2										
3										
4						1'; silt with clay and coral fragments 1/4"-1/2". SAA otherwise from 1-10' bgs				
5										
6										
7										*End of coral @ 7'
8										
9										
10		X	12 24	12"		10' Silty Clay with some weathered minerals. Conglomerated texture, Blocky, Dark Rusty Brown w/orange weathered minerals, No odor or staining, slightly moist.				2 ppm Ambient 9 ppm Boggie NDSP
11										
12										
13										
14										Fast Drilling
15										
16										
17										
18										18' noticed color change to lighter Brown
19										
20		X	50	6"	SAPROLITE	20'; Saprolite - Light orange Brown w/ multi colored minerals, olivine, pyroxene and some secondary calcite and organics Slight Horizontal Fractures. Consolidated and well sorted. No staining or odor. Very Dry. Non vesicular				0 ppm Ambient 3 ppm Boggie NDSP
21										
22										
23										
24										
25										Drilling slowed down a little
26										
27										
28										
29										29' first odor detected
30		X				See next page for 30-31' sample				

Engineering-Science, Inc. | PROJECT NO.

PROJECT:
LOCATION ID: H1-2-MP13

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
31–39		X	9 13	12"	SAPROLITE ↓	31'; Saprolite, Reddish Brown with orange and Red weathered patches, Blocky and moderate Consolidation vesicular. No staining. Slight solvent odor, slightly moist.				0 ppm Ambient; 100 ppm Baggie HDSP; -@ 30' color change from Dark Brown to Reddish color ↓ Fast Drilling again ↓
40–49		X	23 70	12"	grout ▽	40'; Saprolite, Highly weathered to a clay texture. Rusty Red Brown with few yellow patches. Very Consolidated Blocky, Non vesicular, Slightly moist, odor present, no staining				0 ppm ambient; 240 ppm Baggie HDSP ↓ Fast Drilling ↓ @ 47-50' Hard Drilling and Stronger Hydrocarbon odor. Possibly due to water; @ 48' - water Encountered
50–60		X	6 7 13 13	24"	grout / grout /	50'; Saprolite, Dark Rusty Brown, Some green weathered patches. moderately consolidated, clumpy with some Horizontal Fractures. Slightly vesicular, moist, no staining, little odor.				-0 ppm Ambient; -1800 ppm baggie HDSP; Fast Drilling ↓ @ 60' - Stop Drilling w/ 10¼" Auger. grouted from 60' up to 43'

NOTES: HDSP = Head Space

PROJECT:
LOCATION ID: 8 NE-2-MPB

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
61					↑					-Drilled Through grout From 43'-60' with 8" Auger, no water Present
2										
3										
4					S					
5		☒	30	6"	A	65; Saprolite, SAA				
6					P					Drilling @ moderate Speed
7					R,					
8					O					-2 ppm Ambient
9					L					-16 ppm Boggie Nose
70					I					-Cutting Are Having trouble Coming out of hole
1					T					
2					E					
3										
4					↓					
75		☒	?	0"		75'; SAProlite, SAA / DBGS 75'				-@75' noticed water in hole Again. Bad grout mixture or possibly cracked From augers
6										
7										
8										
9										-@75' Sample fell out of Split Spoon
1										
2										
3										
4										
5										
6										
7										
8										
9										

NOTES:

PROJECT:
LOCATION ID.: SITE 2- MPC

LOG OF BORING:

DATE STARTED: 4-8-93

DATE COMPLETED:

DRILLING METHOD: HSA

SAMPLING METHOD: Split Spoon

DRILLER: Geolabs

GEOLOGIST/ENGINEER: Craig Miller / John Ratz

NOTES:

BOREHOLE DIAMETER: 8"

SURFACE CONDITIONS: 75°F; Cloudy, asphalt & grass

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C.	NOTES
1						2"; Black asphalt				
2						1'; Silt with clay and coral fragments				
3						1.5"-3.0". Some organics. Rust				- Easy
4						Brown. Loosely consolidated. DRY.				Drilling
5						No odor or staining.				
6						(1-9' BGS)				
7										
8										* @ 7' Feet coral
9		X	?	6"		9'; Silt, with clay. Rust Brown				fragments End.
10						with orange weathered patches.				0.0 ppm ambient
11						Blocky, moderately consolidated.				0.3 ppm baggie HDSP
12						Slightly moist. No odor or staining.				
13										
14										* @ 15' color
15										change to Dark
16										Brown
17										
18										
19		X	?	8"		19'; Clay with silt. - Dark Brown.				0.0 ppm ambient
20						moderately consolidated. Low plasticity,				0.0 ppm baggie HDSP
21						stickiness, & stiffness. Slightly moist.				
22						No odor or staining.				
23										* Slight Lithology
24										Change @ 21' BGS
25										
26										- Drilling
27										slower
28										
29		X		12"	SAPROLITE	29'; Saprolite, - TAN. moderately				0.0 ppm ambient
30						consolidated, Blocky. Non vesicular				0.0 ppm baggie HDSP.
						Slightly moist. Very sticky. No odor or staining.				

Engineering-Science, Inc.

PROJECT NO.

PROJECT:
LOCATION ID: SITE 2-MPC

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	USCS	L C	NOTES
31										
2					S					Drilling easy again
3					A					
4					P					
5					R					
6					O					
7					L					
8					I					
9		X	?	12"	T	39; Saprolite - Reddish Brown, Highly Consolidated. Non vesicular clay like texture. Slightly moist. No odor or staining.				
40					E					0.0 ppm Ambient
1										0.0 ppm baggie HDSP
2										
3										
4										
5										
6										
7										
8										
9		X	?	12"		49; Saprolite - Brownish Black with Red patches. Loosly consolidated. Has gritty texture. Saturated. No odor or staining				* WATER found @ 49' BGS
50										
1										
2										-Drilling slowing Down
3										
4										
5										
6										
7										@57' cuttings coming up wet
8										
9		X	?	12"		59; Saprolite - TAN, moderately Consolidated. Non vesicular. Very Sticky. Slightly moist. No odor or Staining				0.0 ppm Ambient
60										36.8 ppm baggie HDSP

NOTES: HDSP = HeadSpace

PROJECT:
LOCATION ID: SITE 2 - MAC

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C	NOTES
61					S					
2					A					
3										
4		X	?	12"	P	64' SAPROLITE - Dark Rusty Brown				
5					R	with Black olivine particles. moderately				0.0 ppm Ambient
6					O	Consolidated. Vesicular (3-6mm).				4.3 ppm Breathing Zone
7					L	Slightly moist. No odor or staining				* LAST split
8					I					Spoon taken
9					T					@ 64-65' B95
70					E					
1										
2										
3										
4										
5						TOBGS @ 75'				
6										
7										
8										
9										
1										
2										
3										
4										
5										
6										
7										
8										
9										

NOTES:

PROJECT: LOCATION ID: SITE Z - Background	LOG OF BORING:
DATE STARTED: 3-29-93	GEOLOGIST/ENGINEER: CRAIG miller / John Rotz
DATE COMPLETED:	NOTES:
DRILLING METHOD: HSA	BOREHOLE DIAMETER: 8"
SAMPLING METHOD: Split Spoon	SURFACE CONDITIONS: Sunny 80°F, grass Lands
DRILLER: GeoLABS	

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C.	NOTES
1						1' Clay with Silt - 90% clay 10% silt. Some organics. Reddish Brown, loosly Consolidated. Low plasticity, stickiness, and stiffness, very Dry. No odor or staining.				FAST Drilling
2										
3										
4										
5										
6										
7										
8										
9										
10		X	55 32	6"		10' Clay grading to Silt. DRY SAA				0.0 ppm Ambient 27.5 ppm Baggie HDSp
11										
12										
13										
14										
15										FAST Drilling
16										
17										
18										
19										
20		X	?	18"		20' Silt and clay; 60% silt 40% clay. Reddish Brown, moderately Consolidated Low plasticity, moderate stickiness and stiffness. DRY. No odor or Staining				0.0 ppm Ambient 40.1 ppm baggie HDSp
21										
22										
23										* Drilling Slowing Down some Having to Switch gears often
24										
25										
26										
27										
28										
29										
30										

PROJECT:
LOCATION ID: Site 2 - Background | LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
31		X	?	18"		31'; Silt with clay 65% silt 40% clay. Dark Brown. moderately consolidated. Blocky. moderate Stickiness. No odor or staining				0.0 ppm ambient
2										42.5 ppm baggie HdSp
3										* Lithology change
4										- Cuttings still coming up slow
5						35'; Saprolite; Dark Reddish Brown, non vesicular, well consolidated. clay like in Lithology, slightly moist no odor or staining				
6										
7					S					
8					A					
9					P					
40		X	?	6"	R	40; Saprolite-SAA, slightly moist				0.0 ppm ambient
1					O					32.4 ppm baggie HdSp
2					L					
3					I					
4					T					
5					E					
6										
7										
8										
9										
50						50; Saprolite; SAA, moist				
1										
2										
3										
4										
55										* Cutting not coming out of hole. Rig does not have enough torque. Need to change Rigs.
6										
7										
8										
9										
60										

NOTES: HDSP = HEADSPACE

PROJECT:
LOCATION ID: SITE-Z-Background

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L C	NOTES
61										
65		X	?	12"	SAPROLITE	65'; Saprolite - SAA				0.0 ppm ambient 22.1 ppm baggie HDSP
70										Drilling Speed moderate
80		X	?	12"		80'; Saprolite - SAA				0.0 ppm Ambient 13.5 ppm baggie HDSP
90										

NOTES:

PROJECT:
LOCATION ID: SITE 2 - Background

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	CODE L.C.	NOTES
91		X	7	6"	S	90'; Saprolite - SAA				0.0 ppm Ambient 10.8 ppm baggie HDSp.
2					A					
3					P					
4					R					
5					O					
6					L					
7					I					
8					T					
9					E					
100		X	12 21 55	3"		100'; Saprolite - SAA				0.0 ppm Ambient 43.5 ppm baggie HDSp
1						TD B65				
2						@				
3						100' B95				
4										
5										
6										
7										
8										
9										
1										
2										
3										
4										
5										
6										
7										
8										
9										

NOTES: